AIR FORCE
15.1 Small Business Innovation Research (SBIR)
Proposal Submission Instructions

INTRODUCTION

The Air Force (AF) proposal submission instructions are intended to clarify the Department of Defense (DoD) instructions as they apply to AF requirements.

The Air Force Research Laboratory (AFRL), Wright-Patterson Air Force Base, Ohio, is responsible for the implementation and management of the AF Small Business Innovation Research (SBIR) Program.

The AF Program Manager is Mr. David Sikora, 1-800-222-0336. For general inquiries or problems with the electronic submission, contact the DoD Help Desk at 1-866-724-7457 (1-866-SBIRHLP) (8:00 a.m. to 5:00 p.m. ET Monday through Friday). For technical questions about the topics during the pre-solicitation period (12 December 2014 through 14 January 2015), contact the Topic Authors listed for each topic on the Web site. For information on obtaining answers to your technical questions during the formal solicitation period (15 January through 18 February 2015), go to http://www.dodsbir.net/sitis/.

General information related to the AF Small Business Program can be found at the AF Small Business website, http://www.airforcesmallbiz.org. The site contains information related to contracting opportunities within the AF, as well as business information, and upcoming outreach/conference events. Other informative sites include those for the Small Business Administration (SBA), www.sba.gov, and the Procurement Technical Assistance Centers, www.aptacus.org/new/Govt_Contracting/index.php. These centers provide Government contracting assistance and guidance to small businesses, generally at no cost.

The AF SBIR Program is a mission-oriented program that integrates the needs and requirements of the AF through R&D topics that have military and/or commercial potential.

Efforts under the SBIR program fall within the scope of fundamental research. The Under Secretary of Defense (Acquisition, Technology, & Logistics) defines fundamental research as "basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community," which is distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons. See DFARS 252.227-7018 for a description of your SBIR/STTR rights.

PHASE I PROPOSAL SUBMISSION

Read the DoD program solicitation at www.dodsbir.net/solicitation for program requirements. When you prepare your proposal, keep in mind that Phase I should address the feasibility of a solution to the topic. For the AF, the contract period of performance for Phase I shall be nine (9) months, and the award shall not exceed $150,000. We will accept only one Cost Volume per Topic Proposal and it must address the entire nine-month contract period of performance.

The Phase I award winners must accomplish the majority of their primary research during the first six months of the contract. Each AF organization may request Phase II proposals prior to the completion of the first six months of the contract based upon an evaluation of the contractor's technical progress and review by the AF technical point of contact utilizing the criteria in section 6.0 of the DoD solicitation. The last three months of the nine-month Phase I contract will provide project continuity for all Phase II award winners so no modification to the Phase I contract should be necessary.

The Phase I Technical Volume has a 20-page-limit (excluding the Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-j), and Company Commercialization Report).

Limitations on Length of Proposal

The Technical Volume must be no more than 20 pages (no type smaller than 10-point on standard 8-1/2" x 11" paper with one (1) inch margins. The Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-j), and Company Commercialization Report are excluded from the 20 page limit. Only the Technical Volume and any enclosures or attachments count toward the 20-page limit. In the interest of equity, pages in excess of the 20-page limitation (including attachments, appendices, or references, but excluding the Cover Sheet, Cost Volume, Cost Volume Itemized Listing (a-j), and Company Commercialization Report, will not be considered for review or award.

Phase I Proposal Format

Proposal Cover Sheet: The Cover Sheet does NOT count toward the 20 page total limit. If your proposal is selected for award, the technical abstract and discussion of anticipated benefits will be publicly released on the Internet; therefore, do not include proprietary information in these sections.

Technical Volume: The Technical Volume should include all graphics and attachments but should not include the Cover Sheet or Company Commercialization Report (as these items are completed separately). Most proposals will be printed out on black and white printers so make sure all graphics are distinguishable in black and white. It is strongly encouraged that you perform a virus check on each submission to avoid complications or delays in submitting your Technical Volume. To verify that your proposal has been received, click on the “Check Upload” icon to view your proposal. Typically, your uploaded file will be virus checked. However, if your proposal does not appear after an hour, please contact the DoD Help Desk at 1-866-724-7457 (8:00 am to 5:00 pm ET Monday through Friday).

Key Personnel: Identify in the Technical Volume all key personnel who will be involved in this project; include information on directly related education, experience, and citizenship. A technical resume of the principle investigator, including a list of publications, if any, must be part of that information. Concise technical resumes for subcontractors and consultants, if any, are also useful. You must identify all U.S. permanent residents to be involved in the project as direct employees, subcontractors, or consultants. You must also identify all non-U.S. citizens expected to be involved in the project as direct employees, subcontractors, or consultants. For all non-U.S. citizens, in addition to technical resumes, please provide countries of origin, the type of visa or work permit under which they are performing and an explanation of their anticipated level of involvement on this project, as appropriate. You may be asked to provide additional information during negotiations in order to verify the foreign citizen’s eligibility to participate on a contract issued as a result of this solicitation.

Voluntary Protection Program (VPP): VPP promotes effective worksite-based safety and health. In the VPP, management, labor, and the Occupational Safety and Health Agency (OSHA) establish cooperative relationships at workplaces that have implemented a comprehensive safety and health management system. Approval into the VPP is OSHA’s official recognition of the outstanding efforts of employers and employees who have achieved exemplary occupational safety and health. An “Applicable Contractor” under the VPP is defined as a construction or services contractor with employees working at least 1,000 hours at the site in any calendar quarter within the last 12 months that is NOT directly supervised by the applicant (installation). The definition flows down to affected subcontractors. Applicable contractors will be required to submit Days Away, Restricted, and Transfer (DART) and Total Case Incident (TCIR) rates for the past three years as part of the proposal. Pages associated with this information will NOT contribute to the overall Technical Volume page count. NOTE: If award of your firm's proposal does NOT create a situation wherein performance on one Government installation will exceed 1,000 hours in one calendar quarter, **SUBMISSION OF TCIR/DART DATA IS NOT REQUIRED.**

Phase I Work Plan Outline

NOTE: THE AF USES THE WORK PLAN OUTLINE AS THE INITIAL DRAFT OF THE PHASE I STATEMENT OF WORK (SOW). THEREFORE, DO NOT INCLUDE PROPRIETARY INFORMATION IN THE WORK PLAN OUTLINE. TO DO SO WILL NECESSITATE A REQUEST FOR REVISION AND MAY DELAY CONTRACT AWARD.

At the beginning of your proposal work plan section, include an outline of the work plan in the following format:

1) Scope
   List the major requirements and specifications of the effort.
2) Task Outline
   Provide a brief outline of the work to be accomplished over the span of the Phase I effort.
3) Milestone Schedule
4) Deliverables
   a. Kickoff meeting within 30 days of contract start
   b. Progress reports
   c. Technical review within 6 months
   d. Final report with SF 298

Cost Volume

Cost Volume information should be provided by completing the on-line Cost Volume form and including the Cost Volume Itemized Listing (a-j) specified below. The Cost Volume detail must be adequate to enable Air Force personnel to determine the purpose, necessity and reasonability of each cost element. Provide sufficient information (a-j below) on how funds will be used if the contract is awarded. The on-line Cost Volume and Itemized Cost Volume Information (a-j) will not count against the 20-page limit. The itemized listing may be placed in the "Explanatory Material" section of the on-line Cost Volume form (if enough room), or as the last page(s) of the Technical Volume Upload. (Note: Only one file can be uploaded to the DoD Submission Site). Ensure that this file includes your complete Technical Volume and the Cost Volume Itemized Listing (a-j) information.

a. Special Tooling and Test Equipment and Material: The inclusion of equipment and materials will be carefully reviewed relative to need and appropriateness of the work proposed. The purchase of special tooling and test equipment must, in the opinion of the Contracting Officer, be advantageous to the Government and relate directly to the specific effort. They may include such items as innovative instrumentation and/or automatic test equipment.

b. Direct Cost Materials: Justify costs for materials, parts, and supplies with an itemized list containing types, quantities, and price and where appropriate, purposes.

c. Other Direct Costs: This category of costs includes specialized services such as machining or milling, special testing or analysis, costs incurred in obtaining temporary use of specialized equipment. Proposals, which include leased hardware, must provide an adequate lease vs. purchase justification or rational.

d. Direct Labor: Identify key personnel by name if possible or by labor category if specific names are not available. The number of hours, labor overhead and/or fringe benefits and actual hourly rates for each individual are also necessary.

e. Travel: Travel costs must relate to the needs of the project. Break out travel cost by trip, with the number of travelers, airfare, per diem, lodging, etc. The number of trips required, as well as the destination and purpose of each trip should be reflected. Recommend budgeting at least one (1) trip to the Air Force location managing the contract.

f. Cost Sharing: Cost sharing is permitted. However, cost sharing is not required nor will it be an evaluation factor in the consideration of a proposal. Please note that cost share contracts do not allow fees. NOTE: Subcontract arrangements involving provision of Independent Research and Development (IR&D) support are prohibited in accordance with Under Secretary of Defense (USD) memorandum "Contractor Cost Share", dated 16 May 2001, as implemented by SAF/AQ memorandum, same title, dated 11 Jul 2001.

g. Subcontracts: Involvement of university or other consultants in the planning and/or research stages of the project may be appropriate. If the offeror intends such involvement, describe in detail and include information in the Cost Volume. The proposed total of all consultant fees, facility leases or usage fees, and other subcontract or purchase agreements may not exceed one-third of the total contract price or cost, unless otherwise approved in writing by the Contracting Officer. Support subcontract costs with copies of the subcontract agreements. The supporting agreement documents must adequately describe the work to be performed (i.e., Cost Volume). At a minimum, an offeror must include a Statement of Work (SOW) with a corresponding detailed Cost Volume for each planned subcontract.

h. Consultants: Provide a separate agreement letter for each consultant. The letter should briefly state what service or assistance will be provided, the number of hours required and hourly rate.

i. Any exceptions to the model Phase I purchase order (P.O.) found at https://www.afsbirsttr.com/Proposals/Default.aspx (see "NOTE" below)

NOTE: If no exceptions are taken to an offeror's proposal, the Government may award a contract without discussions (except clarifications as described in FAR 15.306(a)). Therefore, the offeror's initial proposal should contain the offeror's best terms from a cost or price and technical standpoint. In addition, please review the model Phase I P.O. found at https://www.afsbirsttr.com/Proposals/Default.aspx and provide any exception to the clauses found therein with your cost proposal Full text for the clauses included in the P.O. may be found at http://farsite.hill.af.mil. **If selected for award, the award contract or P.O. document received by your firm may vary in format/content from the model P.O. reviewed. If there are questions regarding the award document, contact the Phase I Contracting Officer listed on the selection notification.** (See item g under the "Cost Volume" section, p. AF-4.) The Government reserves the right to conduct discussions if the Contracting Officer later determines them to be necessary.

j. DD Form 2345: For proposals submitted under export-controlled topics (either International Traffic in Arms (ITAR) or Export Administration Regulations (EAR)), a copy of the certified DD Form 2345, Militarily Critical Technical Data Agreement, or evidence of application submission must be included. The form, instructions, and FAQs may be found at the United States/Canada Joint Certification Program website, http://www.dlis.dla.mil/jcp/. Approval of the DD Form 2345 will be verified if proposal is chosen for award.

NOTE: Only Government employees and technical personnel from Federally Funded Research and Development Centers (FFRDCs) Mitre and Aerospace Corporations, working under contract to provide technical support to AF Life Cycle Management Center and Space and Missiles Centers may evaluate proposals. All FFRDC employees have executed non-disclosure agreement (NDAs) as a requirement of their contracts. Additionally, AF support contractors may be used to administratively or technically support the Government's SBIR Program execution. DFARS 252.227-7025, Limitations on the Use or Disclosure of Government-Furnished Information Marked with Restrictive Legends (Mar 2011), allows Government support contractors to do so without company-to-company NDAs only AFTER the support contractor notifies the SBIR firm of its access to the SBIR data AND the SBIR firm agrees in writing no NDA is necessary. If the SBIR firm does not agree, a company-to-company NDA is required. The attached "NDA Requirements Form" (page 9) must be completed, signed, and included in the Phase I proposal, indicating your firm's determination regarding company-to-company NDAs for access to SBIR data by AF support contractors. This form will not count against the 20-page limitation.

PHASE I PROPOSAL SUBMISSION CHECKLIST

Failure to meet any of the criteria will result in your proposal being **REJECTED** and the Air Force will not evaluate your proposal.

1) The Air Force Phase I proposal shall be a nine-month effort and the cost shall not exceed $150,000.

2) The Air Force will accept only those proposals submitted electronically via the DoD SBIR Web site (www.dodsbir.net/submission).

3) You must submit your Company Commercialization Report electronically via the DoD SBIR Web site (www.dodsbir.net/submission).

It is mandatory that the complete proposal submission -- DoD Proposal Cover Sheet, Technical Volume with any appendices, Cost Volume, Itemized Cost Volume Information, and the Company Commercialization Report -- be submitted electronically through the DoD SBIR Web site at http://www.dodsbir.net/submission. Each of these documents is to be submitted separately through the Web site. Your complete proposal **must** be submitted via the submissions site on or before the **6:00 am ET, 18 February 2015 deadline.** A hardcopy **will not** be accepted.

The AF recommends that you complete your submission early, as computer traffic gets heavy near the solicitation closing and could slow down the system. **Do not wait until the last minute.** The AF will not be responsible for proposals being denied due to servers being "down" or inaccessible. Please assure that your e-mail address listed in your proposal is current and accurate. By late February, you will receive an e-mail serving as our acknowledgement that we have received your proposal. **The AF is not responsible for ensuring notifications are received by firms changing mailing address/e-mail address/company points of contact after proposal submission without proper notification to the AF. Changes of this nature that occur after proposal submission or award (if selected) for Phase I and II shall be sent to the Air Force SBIR/STTR site address, afprogram@afsbirsttr.net.**

AIR FORCE SBIR/STTR SITE

As a means of drawing greater attention to SBIR accomplishments, the AF has developed a SBIR/STTR site at http://www.afsbirsttr.com. Along with being an information resource concerning SBIR policies and procedures, the SBIR/STTR site is designed to help facilitate the Phase III transition process. To this end, the SBIR/STTR site contains SBIR/STTR Success Stories written by the Air Force and Phase II summary reports written and submitted by SBIR companies. Since summary reports are intended for public viewing via the Internet, they should not contain classified, sensitive, or proprietary information.

AIR FORCE PROPOSAL EVALUATIONS

The AF will utilize the Phase I proposal evaluation criteria in section 6.0 of the DoD solicitation in descending order of importance with technical merit being most important, followed by the qualifications of the principal investigator (and team), and followed by Commercialization Plan. The AF will utilize Phase II evaluation criteria in section 8.0 of the DoD solicitation; however, the order of importance will differ. The AF will evaluate proposals in descending order of importance with technical merit being most important, followed by the Commercialization Plan, and then qualifications of the principal investigator (and team). Please note that where technical evaluations are essentially equal in merit, and as cost and/or price is a substantial factor, cost to the Government will be considered in determining the successful offeror. The next tie-breaker on essentially equal proposals will be the inclusion of manufacturing technology considerations.

The proposer's record of commercializing its prior SBIR and STTR projects, as shown in its Company Commercialization Report, will be used as a portion of the Commercialization Plan evaluation. If the "Commercialization Achievement Index (CAI)", shown on the first page of the report, is at the 20th percentile or below, the proposer will receive no more than half of the evaluation points available under evaluation criterion (c) in Section 6 of the DoD 14.1 SBIR instructions. This information supersedes Paragraph 4, Section 5.4e, of the DoD 15.1 SBIR instructions.

A Company Commercialization Report showing the proposing firm has no prior Phase II awards will not affect the firm's ability to win an award. Such a firm's proposal will be evaluated for commercial potential based on its commercialization strategy.

On-Line Proposal Status and Debriefings

The AF has implemented on-line proposal status updates for small businesses submitting proposals against AF topics. At the close of the Phase I Solicitation – and following the submission of a Phase II via the DoD SBIR/STTR Submission Site (https://www.dodsbir.net/submission) – small business can track the progress of their proposal submission by logging into the Small Business Area of the AF SBIR/STTR site (http://www.afsbirstr.com). The Small Business Area (http://www.afsbirsttr.com/Firm/login.aspx) is password protected and firms can view their information only.

To receive a status update of a proposal submission, click the "Proposal Status" link at the top of the page in the Small Business Area (after logging in). A listing of proposal submissions to the AF within the last 12 months is displayed. Status update intervals are: Proposal Received, Evaluation Started, Evaluation Completed, Selection Started, and Selection Completed. A date will be displayed in the appropriate column indicating when this stage has been completed. If no date is present, the proposal submission has not completed this stage. Small businesses are encouraged to check this site often as it is updated in real-time and provides the most up-to-date information available for all proposal submissions**. Once the "Selection Completed" date is visible, it could still be a few weeks (or more) before you are contacted by the AF with a notification of selection or non-selection.** The AF receives thousands of proposals during each solicitation and the notification process requires specific steps to be completed prior to a Contracting Officer distributing this information to small business.

The Principal Investigator (PI) and Corporate Official (CO) indicated on the Proposal Cover Sheet will be notified by e-mail regarding proposal selection or non-selection. The e-mail will include a link to a secure Internet page containing specific selection/non-selection information. Small Businesses will receive a notification for each proposal submitted. Please read each notification carefully and note the Proposal Number and Topic Number referenced. **Again, if changes occur to the company mail or email address(es) or company points of contact afte proposal submission, the information shall be provided to the AF at afprogram@afsbirsttr.net.**

A debriefing may be received by written request. As is consistent with the DoD SBIR/STTR solicitation, the request must be received within 30 days after receipt of notification of non-selection. Written requests for debrief must be uploaded to the Small Business Area of the AF SBIR/STTR site (http://www.afsbirsttr.com). Requests for debrief should include the company name and the telephone number/e-mail address for a specific point of contract, as well as an alternate. Also include the topic number under which the proposal(s) was submitted, and the proposal number(s). Further instructions regarding debrief request preparation/submission will be provided within the Small Business Area of the AF SBIR/STTR site. Debrief requests received more than 30 days after receipt of notification of non-selection will be fulfilled at the Contracting Officers' discretion. Unsuccessful offerors are entitled to no more than one debriefing for each proposal.

IMPORTANT: Proposals submitted to the AF are received and evaluated by different offices within the Air Force and handled on a Topic-by-Topic basis. Each office operates within their own schedule for proposal evaluation and selection**. Updates and notification timeframes will vary by office and Topic. If your company is contacted regarding a proposal submission, it is not necessary to contact the AF to inquire about additional submissions.** Check the Small Business Area of the AF SBIR/STTR site for a current update. Additional notifications regarding your other submissions will be forthcoming.

We anticipate having all the proposals evaluated and our Phase I contract decisions within approximately three months of proposal receipt. **All questions concerning the status of a proposal, or debriefing, should be directed to the local awarding organization SBIR Program Manager.** Organizations and their Topic Numbers are listed later in this section (before the Air Force Topic descriptions).

PHASE II PROPOSAL SUBMISSIONS

Phase II is the demonstration of the technology that was found feasible in Phase I. Only Phase I awardees are eligible to submit a Phase II proposal. All Phase I awardees will be sent a notification with the Phase II proposal submittal date and a link to detailed Phase II proposal preparation instructions. If the mail or email address(es) or firm points of contact havechanged since submission of the Phase I proposal, correct information shall be sent to the AF at afprogram@afsbirsttr.net. Please note that it is solely the responsibility of the Phase I awardee to contact this individual. Phase II efforts are typically two (2) years in duration with an initial value not to exceed $750,000.

NOTE: All Phase II awardees must have a Defense Contract Audit Agency (DCAA) approved accounting system. It is strongly urged that an approved accounting system be in place prior to the AF Phase II award timeframe. If you do not have a DCAA approved accounting system, this will delay / prevent Phase II contract award. If you have questions regarding this matter, please discuss with your Phase I Contracting Officer.

All proposals must be submitted electronically at www.dodsbir.net/submission. The complete proposal – Department of Defense (DoD) Cover Sheet, entire Technical Volume with appendices, Cost Volume and the Company Commercialization Report – must be submitted by the date indicated in the invitation. The

Technical Volume is **limited to 50 pages** (unless a different number is specified in the invitation). The Commercialization Report, any advocacy letters, SBIR Environment Safety and Occupational Health (ESOH) Questionnaire, and Cost Volume Itemized Listing (a-i) will not count against the 50 page limitation and should be placed as the last pages of the Technical Volume file that is uploaded. (Note: Only one file can be uploaded to the DoD Submission Site. Ensure that this single file includes your complete Technical Volume and the additional Cost Volume information.) The preferred format for submission of proposals is Portable Document Format (.pdf). Graphics must be distinguishable in black and white. **Please virus-check your submissions**.

AIR FORCE PHASE II ENHANCEMENT PROGRAM

On active Phase II awards, the Air Force may request a Phase II enhancement application package from a limited number of Phase II awardees. In the Air Force program, the outside investment funding must be from a Government source, usually the Air Force or other military service. The selected enhancements will extend the existing Phase II contract awards for up to one year. The Air Force will provide matching SBIR funds, up to a maximum of $750,000, to non-SBIR Government funds. If requested to submit a Phase II enhancement application package, it must be submitted through the DoD Submission Web site at www.dodsbir.net/submission. Contact the local awarding organization SBIR Program Manager (see Air Force SBIR Organization Listing) for more information.

AIR FORCE SBIR PROGRAM MANAGEMENT IMPROVEMENTS

The AF reserves the right to modify the Phase II submission requirements. Should the requirements change, all Phase I awardees will be notified. The AF also reserves the right to change any administrative procedures at any time that will improve management of the AF SBIR Program.

AIR FORCE SUBMISSION OF FINAL REPORTS

All Final Reports will be submitted to the awarding AF organization in accordance with the Contract. Companies **will not** submit Final Reports directly to the Defense Technical Information Center (DTIC).

AIR FORCE
15.1 Small Business Innovation Research (SBIR)
Non-Disclosure Agreement (NDA) Requirements

DFARS 252.227-7018(b)(8), Rights in Noncommercial Technical Data and Computer Software – Small Business Innovation Research (SBIR) Program (May 2013), allows Government support contractors access to SBIR data without company-to-company NDAs only AFTER the support contractor notifies the SBIR firm of its access to the SBIR data AND the SBIR firm agrees in writing no NDA is necessary. If the SBIR firm does not agree, a company-to-company NDA is required.

"Covered Government support contractor" is defined in 252.227-7018(a)(6) as "a contractor under a contract, the primary purpose of which is *to furnish independent and impartial advice or technical assistance directly to the Government in support of the Government's management and oversight of a program or effort* (rather than to directly furnish an end item or service to accomplish a program or effort), provided that the contractor—

> (i) Is not affiliated with the prime contractor or a first-tier subcontractor on the program or effort, or with any direct competitor of such prime contractor or any such first-tier subcontractor in furnishing end items or services of the type developed or produced on the program or effort; and
>
> (ii) Receives access to the technical data or computer software for performance of a Government contract that contains the clause at 252.227-7025, Limitations on the Use or Disclosure of Government-Furnished Information Marked with Restrictive Legends."

USE OF SUPPORT CONTRACTORS:

Support contractors may be used to administratively process SBIR documentation or provide technical support related to SBIR contractual efforts to Government Program Offices.

Below, please provide your firm's determination regarding the requirement for company-to-company NDAs to enable access to SBIR documentation by Air Force support contractors. This agreement must be signed and included in your Phase I/II proposal package

☐ YES ☐ NO Non-Disclosure Agreement Required
(If Yes, include your firm's NDA requirements in your proposal)

Company: ______________________ Proposal Number: ______________________
Address: ______________________ City/State/Zip: ______________________
Proposal Title: ____

Name ______________________________ Date: ____________________
Title/Position ______________________________

Air Force SBIR 15.1 Topic Index

AF151-001	Real Time Computer Vision
AF151-002	Electrically-Small Superconducting Wide-Bandwidth Receiver Based on Series Arrays of Nano-Josephson Junctions
AF151-003	Transparent High Reflective Index IR Polymers
AF151-004	Scaled Hypersonic Test Bed
AF151-005	Integrated Photonics
AF151-008	Automated Assessment of Damage to Infrastructure
AF151-009	Compact, low-cost, energy-efficient detector for gamma rays and neutrons
AF151-010	Tool to Assess State of Digital System after Electromagnetic Disruption
AF151-011	Tool for Assessing the Recuperation Time from an Electromagnetic Disruption for a Digital System
AF151-012	Airborne Fuel Cell Prime Power for Weapons Systems
AF151-013	Materials and Designs for Compact High-Voltage Vacuum Insulator Interfaces
AF151-014	Breakdown Resistant Materials for HPM Sources
AF151-015	Transforming Cyber Data into Human-Centered Visualizations
AF151-016	Improved Version of Solid State Night Vision Sensor
AF151-017	Cockpit Passive Optical Helmet Tracker (CPOHT)
AF151-018	1360 Digital Panoramic Night Vision Goggle (DPNVG)
AF151-019	Optimized Information Display for Tactical Air Control Party
AF151-020	F-35 Display Improvement
AF151-021	Full-Scale Near-Field Acoustic Holography for Reduction of Annoyance and Disturbance
AF151-022	Realistic Micro-structured Devices to Mimic Organs for In Vitro Aerospace Toxicology
AF151-023	Breathing Air Quality Sensor (BAQS) for High Performance Aircraft
AF151-024	Advanced Learning Management System (LMS) for State-of-the-Art for Personalized Training
AF151-025	Multi-Channel, High Resolution, High Dynamic Range, Broadband RF Mapping System
AF151-026	Phantom Head for Transcranial Direct Current Stimulation Current Model Validation
AF151-028	Semantic Technology for Logistics Systems Interoperability and Modernization
AF151-029	Infrastructure Agnostic Solutions for Anti-Reconnaissance and Cyber Deception
AF151-030	Cyber Hardening and Agility Technologies for Tactical IP Networks (CHATTIN)
AF151-031	Malicious Behavior Detection for High Risk Data Types (DetChambr)
AF151-032	MIMO functionality for Legacy Radios
AF151-033	Virtual Trusted Platform Module (vTPM)
AF151-034	Target Based Data Compression Settings Broker
AF151-035	Miniature Link-16 Communications Device
AF151-036	Adaptive Agentless Host Security
AF151-037	Special Operations Forces Multi-function Radio
AF151-038	Host-Based Solutions for Anti-Reconnaissance and Cyber Deception
AF151-039	Mediated Mobile Access (MMA)
AF151-040	On-Aircraft Cloud-Based App to Provide Enhanced EO/IR/SAR/Radar Sensor Exploitation
AF151-041	Decision Support Tool Using Gridded Weather Data
AF151-042	Hierarchical Dynamic Exploitation of FMV (HiDEF)
AF151-045	Safety Critical Implementations of Real-Time Data Distribution Middleware
AF151-047	Electronic Warfare Battle Manager Situation Awareness (EWBM-SA)
AF151-048	Cognitive Augmentation for Distributed Command and Control
AF151-049	Normality Modeling and Change Detection for Space Situational Awareness (SSA)
AF151-050	Advanced Detectors for Long Wave Infrared (LWIR) Communications
AF151-051	Built in Test (BIT) Capability for Multi-Mode (MM) Fiber Data Networks
AF151-054	Airfoil Sustainment Through Automated Inspection and Repair
AF151-056	Next-Generation All-Electric Aircraft Auxiliary Power Unit (APU)
AF151-058	Calculated Air Release Point (CARP) Navigation Update Due to Ground Effects (NUDGE)

AF151-059	Advanced Component Cooling Design and Evaluation for Gas Turbine Engines
AF151-060	Common Embedded Vehicle Network Diagnostics Interface Hardware
AF151-061	Fuel-Property-Independent Injection Technology
AF151-062	Low-Weight, High-Temperature Passive Damping System for Afterburners
AF151-063	High-Speed, Two-Dimensional Sensor Suite for Fuel-Air Ratio and Heat-Release Rate for Combustor/Augmentor Stability
AF151-065	Reduced-Order Model for the Prediction of Supersonic Aircraft Jet Noise
AF151-066	Monopropellant Thrusters for Cubesats
AF151-067	Advanced Electrochemical Power Sources and Lithium-Ion Batteries for Space-Launch Vehicles
AF151-068	Solar Electric Propulsion for Agile Space Capabilities
AF151-069	Noncontacting Full-Field Real-Time Strain Measurement System for Air Platforms in Combined Extreme Environments
AF151-070	Modular Motor Drive with Programming and Configuration Tools for the Development of Small Aircraft Electric Power and Propulsion Systems
AF151-071	Compact High Channel Count, High Frequency, Rotating Data Acquisition and Transmission
AF151-072	Ultralightweight Airframe Concepts for Air-launched Intelligence, Surveillance, and Reconnaissance (ISR) Unmanned Aerial Vehicles (UAVs)
AF151-073	Predicting the Flow Interactions of Modular Liquid Rocket Engine Thrust Chambers
AF151-074	Narrow Width Line of Detection
AF151-075	Strategic Hardening of Cold Atom Based Inertial Measurement Units (IMU)
AF151-076	Advanced Solar Array for Dual Launch GPS
AF151-077	Reconfigurable RF Front-end for Multi-GNSS/Communication SDR Receiver
AF151-078	Ephemeral Security Overlay for GPS
AF151-079	Automated Terrestrial EMI Emitter Locator for AFSCN Ground Stations
AF151-080	Long Term Ultrastable Laser System for Space Based Atomic PNT
AF151-081	Novel, Collaborative Tipping and Cueing Methods to Exploit Multiple OPIR Sensors
AF151-082	Environmental Intelligence
AF151-083	Post Processing of Satellite Catalog Data for Event
AF151-084	High-Temperature, Radiation-Hard and High-Efficiency DC-DC Converters for Space
AF151-085	Advanced High Specific Energy Storage Devices Capable of long life and >300 Whr/kg
AF151-086	A Practical Incoherent Scatter Radar
AF151-087	Optimal SSN Tasking to Enhance Real-time Space Situational Awareness
AF151-088	Development of Ultracapacitors with High Specific Energy and Specific Power
AF151-089	Radiation Hardened Digital to Analog Converter
AF151-094	High Power Density Structural Heat Spreader
AF151-095	40 Percent Air Mass Zero Efficiency Solar Cells for Space Applications
AF151-096	Selecting Appropriate Protective Courses of Action when Information-Starved
AF151-097	Space Based Multi-Sensor Data Fusion to Quantify and Assess the Behavior of Earth-Orbiting Artificial Space Object Population
AF151-098	Automated Scaling Software for Oblique Incidence Ionograms
AF151-101	Hardware-in-the-loop Celestial Navigation Test Bed
AF151-102	Novel Penetrator Cases for Explosive and Fuze Survivability
AF151-103	Shock Hardened Laser Targeting System
AF151-104	Rigid-body Off-axis Ordnance Shock/Tail-slap Environment Replicator (ROOSTER)
AF151-105	RF Seeker Performance Improvement in Difficult Environments through Circular Polarization
AF151-106	Develop Advanced Cumulative Damage Models for Multi-Strike RC Bunkers
AF151-107	Long-Range Adaptive Active Sensor
AF151-108	Advanced Multisensor Concepts for Theater Ballistic Missile (TBM) Interceptors
AF151-109	Hostile Fire Detection and Neutralization
AF151-110	Combined Multiple Classification Methods Using Machine Learning Techniques to Develop VIS-N-IR Spectral Processing
AF151-111	Campaign-Level Optimized Strike Planner
AF151-112	Next-Generation Semi-Active Laser (Next Gen SAL)

AF151-113	Miniaturization of RF Seekers
AF151-114	Dynamic Characterization Methods for Composite Materials Systems
AF151-118	Physics-Based Modeling for Specialty Materials at High Temperatures
AF151-119	Development of Flaws in Complex Geometry Coated Turbine Engine Components for Vibrothermography NDE
AF151-120	Linking Coupon to Component Behavior of CMCs in Relevant Service Environment
AF151-121	Improved Life Cycle Management of Airborne Systems Tools
AF151-122	NDI Tool for Corrosion Detection in Sub-Structure
AF151-123	Structural Health Monitoring Methods for Aircraft Structural Integrity
AF151-125	Automated 'Tier 0' Defect Inspection for Low Observable Aircraft
AF151-126	Uncertainty Propagation to Modal Parameters and Metrics
AF151-127	Man-Portable Fire Suppression and Rapid Insulating/Cooling Agent
AF151-128	Robust Titanium Surface Preparation for Structural Adhesive Bonding
AF151-129	Nondestructive Method and Data Analysis for Organic Matrix Composite Leading Edges
AF151-130	High-frequency Applications for Carbon Nanotube-based Wires
AF151-132	Defect Mitigation Processes for III-V-based Infrared Detectors
AF151-133	Optical Materials Processing for High Linearity Electro-optic Modulators
AF151-134	Data Management Tools for Metallic Additive Manufacturing
AF151-135	Research Tool to Support Hybridized Additive Manufacturing
AF151-136	Modeling Tools for the Machining of Ceramic Matrix Composites (CMCs)
AF151-139	Robust Light-Weight Doppler Weather Radar
~~AF151-140~~	(This topic has been removed from the solicitation.)
AF151-141	LWIR Narrow-Band Spectral Filters
AF151-142	Avionics Access Points and Connection Protection
AF151-143	High Speed Non-mechanical Beam Steering for Coherent LIDAR/LADAR
AF151-144	Electronic Warfare Circumvent and Recover
AF151-145	Waveform Agile, Low-cost Multi-function Radio Frequency ISR in Contested Environment
AF151-146	Robust and Reliable Exploitation for Ground Moving Target Detection, Geolocation and Tracking Using Synthetic Aperture Radar
AF151-147	Multiple-Global Navigation Satellite Systems (GNSS) Compatible with Military Global Positioning System (GPS) User Equipment (MGUE)
AF151-148	Space Qualifiable Radiation Hardened Compound Semiconductor Microelectronic Device Technology
AF151-149	Ka-Band and Q-Band Low Noise Amplifiers
AF151-150	Ka-Band Efficient, Linear Power Amplifiers for SATCOM Ground Terminals
AF151-151	Integrated Photonic Optical Circulator
AF151-152	Compact, High Stability Master Oscillators for Airborne Coherent Laser Radar
AF151-154	Influence of Long-range Ionospheric and Atmospheric Effects on Surveillance and Communication Systems
AF151-155	Diffractive Optical Elements for Efficient Laser Cavities
AF151-156	Overhead Persistent Infrared Tracking
AF151-158	Very Large Multi-Modal NDI
AF151-159	Multi-Layer Deep Structure NDI
AF151-160	Alternative Materials to Cu-Be for Landing Gear Bushing/Bearing Applications
AF151-161	Innovative Technologies for Automated Capacity Assessment and Planning for Manufacturing
AF151-162	Non-Destructive Inspection Data Capture
AF151-163	Landing Gear Bushing Installation
AF151-166	Thermal Spray Dashboard/Knowledge Management System
AF151-167	Prognostic Scheduling
AF151-168	Strip Solutions to Optimize the Stripping of Plating and Thermal Spray Coatings
AF151-169	Visual Tire Pressure Indication
AF151-173	Advanced Experimental Design and Modeling and Simulation for Testing Large Format Sensor Arrays
AF151-174	Background-Oriented Schlieren 3D (BOS-3D)

AF151-175	Gigapixel High-Speed Optical Sensor Tracking (GHOST)
AF151-176	Temperature/Heat Flux Imaging of an Aerodynamic Model in High-Temperature, Continuous-Flow Wind Tunnels
AF151-177	Low Power High-Emissivity IR Spatial Uniformity Calibration Source
AF151-178	Infrared Target Collection System (ITCS)
AF151-179	Ground Station Antenna Efficiency Improvements
AF151-180	Recovery Method for Unmanned Hypersonic Test Vehicles
AF151-181	High Accuracy Moving Platform Surveying/Metrology
AF151-182	Computer Assisted Tomography for Three-Dimensional Flow Visualization in Transonic Wind Tunnels
AF151-187	Physics-Based Damage Modeling of Composites for High-Speed Structures
AF151-188	Parametric Inlet Bleed
AF151-189	Reduced-Order Fluid-Thermal-Structural Interactions Model for Control System Design and Assessment
AF151-190	Environmental Sensors for High Speed Airframes
AF151-191	Hypersonic Materials Selection and Integration Tools
AF151-192	Innovative Materials Concepts for Hypersonic Systems
AF151-193	Innovative Synthetic Aperture Radar/Ground Moving Target Indicator (SAR/GMTI) for Hypersonic Air Vehicles
AF151-194	Cognitive Computing Application for Defense Contracting

Air Force SBIR 15.1 Topic Descriptions

AF151-001 TITLE: Real Time Computer Vision

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: The objective is to conceive algorithms that confer the ability to separate video frames into background and foreground components in real time on mobile computing platforms and other limited computational resource devices.

DESCRIPTION: New algorithms based on state-of-the-art machine learning methods are enabling a broad range of transformative technologies. Computer vision applications are no exception. At the forefront of this field is the ability to separate video frames into background and foreground components in real time on mobile computing platforms and other limited computational resource devices. With the growing demand for accurate and real time video surveillance techniques and/or interactive gaming technologies, computationally efficient methods for removing background variations in a video stream (which are generally highly correlated between frames) in order to highlight foreground objects of potential interest are critical in enabling applications at the forefront of modern data analysis research. Background/foreground separation is typically an integral step in detecting, identifying, tracking, and recognizing objects in video sequences. Most modern computer vision applications demand algorithms that can be implemented in real time, and that are robust enough to handle diverse, complicated, and cluttered backgrounds. Competitive methods often need to be flexible enough to accommodate changes in a scene due to, for instance, illumination changes that can occur throughout the day, or location changes where the application is being implemented. Given the importance of this task, a variety of iterative techniques and methods have already been developed in order to perform background/foreground separation. However, they often rely on optimization routines that are computationally expensive, thus compromising their ability to do real time computations with limited resources. New methods being developed must circumvent this prohibitively expensive computation to produce an exceptionally robust, efficient, and potentially game changing technologically, providing a foreground/background separation solution that is two- to three-orders faster than current methods. At such speeds, the algorithm can be very easily implemented on mobile platforms such as smartphones, thus making for a portable field device that can execute such tasks on a mobile phone application type of computing structure. Additionally, a number of technological innovations that can further increase efficiency by determining a small number of pixel locations that are maximally informative about the foreground actions in video streams would make identification and processing of information (for surveillance or gaming applications) even more efficient.

PHASE I: A clear and detailed mathematical framework and implementation strategy is to be developed and test-bedded to demonstrate not only feasibility but the significant reduction in computational expense in comparison with current optimization-based methods. Robustness of the method to a wide variety of video streams needs to be demonstrated with potential weaknesses ascertained.

PHASE II: A user friendly, menu-driven software implementation is sought which can be inserted on a variety of platforms.

PHASE III: In this phase, the uses of the Phase II product by the military, Homeland Security, law enforcement, and by commercial entities are substantially the same.

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KEYWORDS: computer vision, background/foreground separation

AF151-002 TITLE: <u>Electrically-Small Superconducting Wide-Bandwidth Receiver Based on Series Arrays of Nano-Josephson Junctions</u>

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop a wide-bandwidth receiver utilizing series arrays of high-transition-temperature superconducting (HTS) nano Josephson junctions.

DESCRIPTION: There is an ever increasing need for wide bandwidth receivers that are compact in physical size and have high data throughput. An ideal system would have bandwidth large enough to replace multiple systems covering different frequency ranges and would reduce the size, weight and power (SWaP) requirements for operation on mobile platforms. Sensors built from high temperature superconducting (HTS) electronics may be able to fill both of these requirements for realization of this need. A Josephson junction is the active element of superconducting electronics formed by two superconducting electrodes separated by a thin normal metal or insulating barrier. When a phase difference exists across the barrier, a super current will flow in the absence of a voltage where the critical current is the maximum super current sustainable by the barrier. The critical current of a Josephson junction is a function of magnetic field IC(B)= IC |Sinc BA/f0| where A is the area of the junction and f0 is the flux quantum. This effect may be used to detect magnetic field by DC biasing the junction above the critical current and by measuring the resulting voltage. A sensor using a single junction was demonstrated with a voltage to magnetic field response of 50 V/T over a range of about 10 µT. 50 V/T is very modest in comparison to interferometers built from two junctions connected in parallel called SQUIDs (superconducting quantum interference devices). SQUIDs typically achieve 105 V/T [2] and therefore have traditionally been assumed to be the magnetic field detector of choice. However the dynamic range of the SQUID is limited to about 10 nT in comparison to 10 µT for single junctions. Furthermore, the SQUID transfer function is very non-linear so to utilize it as a detector it is typically connected to feedback electronics that limit the bandwidth to a few MHz [2]. Using arrays of very large numbers of nano Josephson junctions will increase the output voltage and therefore sensitivity. The best Josephson junctions for this are nano Josepshon junctions fabricated with ion beam damage [3] because unlike other HTS junction technologies they can be very closely spaced (~150 nm) [4,5], positioned anywhere on a substrate and have excellent temporal stability [6]. Consider a 1 cm chip consisting of a series array of nano Josephson junctions in a meander line. Modestly estimating 400 meanders (25 micron periodicity) with an inter-junction spacing of 0.5 microns yields a total of 8 x 106 Junctions. Assuming a typical single junction ICR product of 10 µV and 50 percent modulation of the critical current to zero this yields 40 V! If only 25 percent of this signal had a usable linear range it would still yield 10 V/10 µT or equivalently 106 V/T which is an order of magnitude better than a SQUID with the added benefits of a large dynamic range, high-linearity and wide-bandwidth.

PHASE I: Perform simulations of devices and investigate the effects of non-uniformity and dimensions on linearity, dynamic range and sensitivity. Build test junction arrays with different design criteria to investigate linearity and voltage response.

PHASE II: Fabricate prototype arrays using the designs developed in Phase I. Characterize devices to determine linearity, bandwidth and gain. Incorporate on-chip bias lines. Measure the noise properties and capabilities of the devices. Test array operation on compact cryocoolers to determine size and weight requirements. Develop support circuitry and develop a prototype wide-band receiver.

PHASE III: Market superconducting circuits and receivers to defense contractors and communication companies.

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5. S. A. Cybart, K. Chen and R. C. Dynes, IEEE Trans. Appl. Supercond. 15, p241, 2005.

6. S. A. Cybart et al. IEEE Trans. Appl. Supercond. 23, p 1100103, 2013.

KEYWORDS: HTS Josephson junctions, wide-bandwidth receiver, superconducting electronics

AF151-003 TITLE: Transparent High Reflective Index IR Polymers

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop high refractive index (>2.0) IR transparent polymers in the 3-5 micron range that are readily melt of solution processible to form optical components such as lens and windows.

DESCRIPTION: Chalcogenide glasses and semiconductor crystals are currently the only materials utilized for 3-5 micron IR optics. Polymers, due to the presence of carbon hydrogen (C-H), or other carbon-heteroatom (C-X) vibrational modes that are strongly IR absorbing in this regime, are traditionally not considered for these applications even though they are widely utilized and proven to be a low cost, lightweight, and mechanically robust material in the visible range. The proposed polymeric materials development would enable a transformative and revolutionary technological advance in IR imaging science.

Recent research demonstrated that sulfur containing co-polymers can provide a wide window of transparency in the IR range. The glass transition temperature can be adjusted to enable melt processing into optical quality components. The solubility can also be adjusted to render the polymers processible with appropriate solvents. The S-S bonds in these polymers can also render them with self-healing characteristics. This topic will exploit these advances to develop a polymeric platform to provide low cost, lightweight, mechanically robust components for IR optics and imaging.

PHASE I: Demonstrate synthesis of polymeric materials with properties that meet the figures of merits as the following: (1) high refractive index values (n > 2.0); (2) low loss, high transparency (alpha< 0.25 cm-1) in 3-5 micron windows; (3) melt and solution processible into thin films, free standing lenses, or optical fibers; (4) with chemistry that are amenable to self-healing upon mechanical damage.

PHASE II: Demonstrate fabrication of optical components such as lens and windows with low cost processing techniques and assess the optical imaging characteristics of these components in the 3-5 micron range. Comparison in performance and cost with traditional IR components will be conducted. Conditions and capability of self-healing characteristics upon damage will be assessed.

PHASE III: Integrate low cost, lightweight, mechanically robust IR optical components into equipment platforms to improve on cost, weight-saving and performance of these platforms.

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1."The Use of Elemental Sulfur as an Alternative Feedstock for Polymeric Materials," Chung, W.-J.; Griebel, J.J.; Kim, E.-T.; Yoon, H. -S.; Simmonds, A.G.; Jon, H.-J.; Dirlam, P.T.; Wie, J.J.; Nguyen, N.A.; Guralnick, B.W.; Park, J.-J.; Somogyi, A.; Theato, P.; Mackay, M.E.; Glass, R.S.; Char, K.-C.; Pyun, J. Nature Chemistry 2013, 5, 518-524.

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3."Sulfur Copolymers for Infrared Optical Imaging," Namnabat, S.; Griebel, J.J.; Pyun, J.; Norwood, R.A.; Dereniak, E.L.; Laan, J. Proc. SPIE 2014, 9070, 90702H-1.

KEYWORDS: IR polymers, transparent from 3-5 micron, self-healing optical polymers, melt and solution processible polymers

AF151-004 TITLE: Scaled Hypersonic Test Bed

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop techniques to integrate new sensing technologies into hypersonic vehicle test article. Collect test article wind tunnel, high speed test track, and other performance data and demonstrate utility for CSE tool application and CFD validation.

DESCRIPTION: The purpose of this topic is to facilitate integration of new sensor technology in a scaled representative hypersonic test article vehicle or cone or wedge and reduce effective model production costs. Basic incorporation of new sensors will facilitate integration of new sensing solutions on relevant hypersonic problems. Physical understanding and modeling of real world hypersonic regimes is required in order to provide invaluable insight into aerodynamics, boundary layer transition, thermal protection systems performance, ablative properties, material effects, scramjet engine operation, and hypersonic instrumentation requirements/optimal locations. Improvements in testing could be realized if new sensing techniques (i.e., modular, transferable to free air test articles, wireless, high density pressure or temperature sensors. etc.) are implemented, potentially resolving issues and reducing uncertainty. The full value hypersonic modeling and simulation requires appropriate validation data for vehicle aerodynamic design, thermal protection systems, scramjet operation, and/or performance. Due to the limited flight testing that has been accomplished on legacy unmanned hypersonic vehicles (X-43, X-51, HTV-2 and HIFiRE) better test data and modeling data is desired. Data collection should be sufficient to the address systematic variations of key parameters needed for computational fluid dynamics (CFD) model validation. In order to assist the acquisition cycle as a whole, high fidelity data sets must be utilized in conjunction with multi-physics computational science and engineering (CSE) tools as applied to these systems. Ultimately these data sets will improve physical understanding and build confidence in the predictive capabilities of CSE tools.

We seek to address this problem through the construction of physical models suitable for high speed test track and wind tunnel testing and capable of providing relevant validation data to assist in CFD model and CSE tool development. We seek to enable state of the art data collection improvements that will advance new testing capabilities and/or reduce risk to programs steps by providing better decision making data. During Phase I, the contractor shall develop one or more representative hypersonic vehicle or hypersonic research cone, wedge, etc., test article designs and assess merits and deficiencies of each with respect to expected performance, fabrication, and testing. Detailed designs and design specifications for each model must be made available in the public domain in electronic format during Phase I and detailed plans to address this requirement must be included in proposals. Phase I proposals must also document the team's ability to fabricate and safely test articles. During Phase II, the contractor shall fabricate one or more of the designed test articles. The new technology must minimize vehicle integration requirements (i.e., weight, size, power, asymmetry). Advanced model construction processes, such as 3D printing, additive manufacturing, or rapid prototyping should be employed, if feasible. Updated public domain designs with actual build specifications for each test article will be provided. Sufficient test data should be collected during Phase II to demonstrate the utility of test article design and fabrication and the ability of test articles to provide relevant validation data. Provisions for public domain access to test data must also be provided. The contractor will also corroborate data and physical characteristics of applicable fluid, structural and/or thermal components through the use of CSE tools. At the end of Phase II, all test articles, designs, design specifications, and performance data shall be delivered to an Air Force facility for additional testing and assessment.

PHASE I: Develop test article design and fabrication techniques. Assess merits and deficiencies of each with respect to expected performance, fabrication, and testing. Designs capable of advancing hypersonic vehicle research are of particular interest, but designs that facilitate hypersonic research article testing are also desired. Develop plans for wind tunnel and high speed test track experiments.

PHASE II: Produce one or more test articles and provide the Air Force design and build specification data. Collect test article wind tunnel, high speed test track and other performance data and demonstrate utility for CSE tool application and CFD modeling and simulation validation. Detailed documentation to be provided at end of Phase II, including all design and test data in electronic form. Test articles, software (source code) and supporting materials delivered and demonstrated at Air Force facility.

PHASE III: Produce new and more complex test article on demand. Demonstrate repeatability of modular sensing solutions, miniaturized transmitters, article measurement, and simulation objectives. Potential customers include Air Force, Navy, NASA, Boeing, Lockheed Martin, and others.

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KEYWORDS: hypersonic, flight test, vehicle recovery method, unmanned, technology demonstration, low power, low weight, small size, test effectiveness, wind tunnel, high speed test track, validation data

AF151-005 TITLE: Integrated Photonics

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop an Integrated Photonic Design platform for enhancing the performance of analog and mixed signal processing modules for military applications.

DESCRIPTION: Efficient electrical-to-optical (E/O) conversion, optical-to-electrical (O/E) conversion, and low loss optical interconnects are imperative for photonic solutions to be competitive with conventional military RF components. E/O and O/E conversion losses coupled with high insertion loss integrated optics have traditionally impaired short-haul RF link performance. Recent progress in optical signal generation, modulation, routing and distribution along with detector technologies are beginning to remove this impairment and create new integrated photonics insertion opportunities for military applications, including but not limited to; ultra wide band receiver for Electronic Warfare (EW), True Time Delay (TDD), photonic switched/controlled solid state antenna, coherent THz Source, Antenna Beam Forming (ABF) and Beam Steering (ABS). The realization and deployment of such applications will highly rely on the ability to overcome the challenge of monolithic integration of analog and mixed RF signal processing modules on a single die. Current state of the art design and development SDKs and fabrication foundries, efficiently address digital integrated photonic designs; however to date, very limited efforts have been aimed towards development of SDK design tools for analog integrated photonic applications. Hence, there is an urgent need for a detailed investigation among available fabrication foundries and material platforms for their suitability in the development of analog integrated photonics for military applications.

Integrated photonics has the potential to meet military needs for decades to come by enhancing the performance of broadband analog and digital signal processing modules like modulators, photodetectors, switches and wavelength division multiplexing and demultiplexing. With recent military/industrial breakthroughs in the integration of photonics in RF systems, the operational bandwidth of military RF systems has increased by orders of magnitude (tens of GHz instead of GHz). In addition, it enabled a significant decrease of the size and a reduction in the power dissipation of military RF systems (i.e., EW, RADAR systems) - far beyond the possibilities of the current electronic RF systems. RF signal pre-processing, filtering and channelization are additional technology areas where photonics can bring value to military RF systems. The performance of the optical link is critical for successful utilization of photonics for military RF systems.

This effort seeks to address the development of an integrated photonic link and further cost and performance improvements as necessary for widespread deployment in military applications. Achieving low noise figure at frequencies to 100 GHz and beyond is highly favorable, along with efficient broadband modulation, compact, high power, low noise laser is also an important area of further integrated photonic device development. Improved link dynamic range is equally important. Broadband photonic link linearizers are needed to push the Spur-Free Dynamic Rang (SFDR) over the 130 dB-Hz2/3 levels.

PHASE I: Develop broadband analog and/or mixed signal optical links. Examine electrical-to-optical (E/O) conversion efficiency, optical-to-electrical (O/E) conversion, efficiency, and low loss optical interconnects to evaluate proposed link designs. Preliminary fabrication processes will be identified for the fabrication of prototypes during Phase II effort.

PHASE II: Develop a standardized design and fabrication platform for the fabrication of integrated analog photonic solutions for military applications. Fabricate and characterize prototypes to validate proposed designs performance. Develop packaging solutions compatible with military platforms including both optical and RF signal I/O signal interface.

PHASE III: Analog/digital integrated photonic solutions for Air Force systems: high-speed photonic enabled A/D, optical signal routing and distribution modules. RF-Photonic links incorporating optical analog processing modules, electrical and RF interconnects.

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KEYWORDS: integrated RF photonic links, RF photonics, analog integrated photonics, InP integrated photonics, silicon photonics, Silicon RF-Photonic

AF151-008 TITLE: Automated Assessment of Damage to Infrastructure

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Consistent infrastructure damage assessment (vertical or horizontal) by autonomously quantifying, in limited time, parameters that express structural capability of affected infrastructure and capacity for use within contingent mission requirements.

DESCRIPTION: As new technologies advance technological capabilities, there remain areas in which human reasoning continues to be a needed element to complete the overall assessment of the condition of infrastructure. Past experience, deductive reasoning, and metadata have been used to support conclusions about structural capability or performance of infrastructure elements that have been subjected to extreme life events or overloads. In this view, there is an evident imbalance between the remotely operated-to-autonomous recovery capabilities following the infrastructure assessment and the infrastructure assessment itself, which is heavily dependent on human reasoning. Advanced technologies, e.g., sensors and other monitoring devices, provide signals from which metadata can be extracted and utilized in an automatic assessment of infrastructure integrity. Sensors like micro-electromechanical sensors and systems (MEMS) can be embedded or added after an event to critical elements of an infrastructure to allow monitoring the performance. External monitoring modalities like cameras and radar afford an additional category of information. The successful technology will combine judicious choices of sensing devices and automated reasoning in conjunction with retrieved metadata to decrease the dependence on human involvement in the infrastructure assessment process.

In the most-desirable eventual embodiment, the technology would attach to and interact with a robot that is one of a robot team directed by the technology, first to conduct the assessment by a process of iterative refinement; then to direct the performance of repairs by the robot team, including emplacement of additional sensors to replace or improve diagnostic capacity; then to conduct a brief second assessment to verify the competence of the repairs and the emplaced sensors. As an installed array, the additional sensors should integrate into a global network that supports different activities from infrastructure assessment to continuous monitoring of conditions at any of the identified critical network nodes or parameters. The sensor technology should have a small footprint, ideally with dimensions allowing monitoring and interaction to the level of a few particles, to match the spatial resolution of a discrete element model---a self-sufficient organic element that can interpret the environment and act consequently. The technology should aim to minimize human intervention and be a self-sufficient partner to other activities that have associated human elements. The combination of advanced reasoning and technology should produce a set of completely independent entities that can monitor, decides, and act without any input from the Command and Control Center, after the "start" decision.

PHASE I: Identify advanced technology(ies) that can provide useful and reliable metadata in support of an automated reasoning and recognition process; identify the reasoning approach and estimate the level of uncertainty and reliability in its output. (Specify performance thresholds for an experimental demonstration of feasibility in several possible scenarios of application).

PHASE II: Develop a prototype of the package designed in Phase I; demonstrate its performance when applied to real-case scenarios (specific scenarios but with variable descriptive parameters). Agreement within 50 percent of human-generated values will be considered successful.

PHASE III: Refine sensor inputs & algorithms to bring agreement with human-generated estimates within 20 percent, configure interfaces for rapid infrastructure assessment to support timely recovery of military infrastructure and for periodic infrastructure assessment in support of generic maintenance planning.

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KEYWORDS: architecture, assessment, autonomous, damage, metadata

AF151-009 TITLE: Compact, low-cost, energy-efficient detector for gamma rays and neutrons

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop an expendable, hand-held or smaller detector system that draws little or no power, quantitatively measures gamma and neutron emissions from radioactive materials and communicates the results wirelessly.

DESCRIPTION: Theft or improper disposal of radioactive isotopes, both as events to be dealt with by first responders and cleanup crews and as potential payloads for environmental weapons dispersing radioactive isotopes (“dirty bombs”), pose a threat to health and safety. Traditional methods for hot-atom detection amplify and detect electrons dislodged from an air or gas sample by alpha or beta emissions; however, as alpha- and beta-emitting isotopes also emit energetic photons (gamma rays), a capability to detect and characterize gamma and neutron emissions should be sufficient to sense and identify hot isotopes in environmental settings. Troops in the field and civilian first responders need a gamma-and-neutron sensor that that is small and rugged enough for hand use in the field to assess post event contamination, guide and monitor the remediation response, and verify at the conclusion of the remediation process that the area is again habitable. A second, highly desirable application for the same sensing technology—broadcast distribution in a state of protracted deployment, reporting electronically to an action center—places a premium on efficiency of energy consumption and independence from external sources of power. Both devices must be inexpensive enough that they can be expendable, responsive within no more than a few minutes of exposure, and at least 99% accurate in detecting emissions; ability to remain in use for extended periods of time without support or maintenance will be useful in the handheld and necessary for the emplaced unit. To provide a useful level of sensitivity and breadth of surface coverage the device should include a durable portal or other aperture that supports detection across a large solid angle, and its sensitivity to materials of interest and capacity to discriminate among them should be equal to or greater than that of existing technology but at lower life-cycle cost and consuming less or, ideally, no externally supplied power.

Desirable features include that the detecting element be small or transparent and colorless (so the user’s view of the area being interrogated is not obscured) and flexible (to conform to different objects and geometries). The ideal embodiment of the broadcast device would perform an initial screening of results and down select to responses exceeding a set threshold, which would be stored as a readable record of results reported, date, time and GPS location, and which could be transmitted wirelessly, on demand, to a central information management unit to be integrated to generate a map of contamination. It is expected that no government materials, data, equipment or facilities will be provided as part of this contract.

PHASE I: Develop a breadboard prototype detector and demonstrate proof of concept through small-scale testing. Target is to detect and discriminate among seven different radioactive isotopes at two emission rates differing by a factor of 10 or more.

PHASE II: Develop a full-scale prototype and test it in the field against an "authentic" detector. For each of 10 different isotopes and 3 controls agreement between the two systems' measurements must be within 20%. Deliverables include a 50% design for a manufacturable prototype and a cost analysis for its production.

PHASE III: Design and produce detectors as part of an outer garment or compatible with operation by minimally trained personnel deployed in rugged environments in full-body protective gear & bulky gloves for use in cargo portals & containers, initial screening for contamination, including under salt water.

REFERENCES:

1. http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/fs-dirty-bombs.html.

2. Leo, W.R. (1994) Techniques for nuclear and particle physics experiments. 2nd Ed. Springer–Verlag. ISBN 0-387-57280-5.

3. Knoll, G.F., (2010) Radiation Detection and Measurement, 4th Ed., John Wiley & Sons.

KEYWORDS: detection, dirty bomb, gamma ray, neutron, radiation, radioactive

AF151-010 TITLE: Tool to Assess State of Digital System after Electromagnetic Disruption

TECHNOLOGY AREAS: Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: The goal of this effort is to build a diagnostic tool that can be used to assess the operational state of each component of a networked computer system after an electromagnetic disruption with relatively fast turn-around time.

DESCRIPTION: The Air Force is moving towards the use of networked commercial off-the-shelf (COTS) electronics for many of its functions, including military operations. This trend is the result of evolving capabilities in COTS electronics; however, it results in new vulnerability for these networked systems. Since many of the networked computer systems are required to operate in a high electromagnetic field environment, it is critical to understand the potential for electromagnetically triggered disruption (upset) of the components of such a system.

Exactly what comprises disruption is only partially known; readily available information is limited to what can be obtained through observation or attempts to interact with a computer in the networked system through, for example, a mouse or keyboard or through specially designed software. This type of assessment simply establishes that the system has been upset and does not provide any information on which is the most vulnerable component in the system or how this upset manifests in this component.

To aid in further developing this understanding of system upset, it would be useful to be able to assess the operating state of each component in a networked system (such as a PC, server, router, switch) after an electromagnetic disruption in order to identify the most vulnerable component(s) in such a networked system and to evaluate how electromagnetically triggered upset manifests in these vulnerable components. It is desirable that this diagnostic tool have fast turnaround time, on the order of minutes.

This SBIR topic is focused on the design and construction of an integrated diagnostic toolset consisting of some combination of the following: remote sensors, hardware attached to the digital device, and software running either at the kernel level or at the application level that monitors the state of the system and provides information that assists in diagnosing the nature of the upset state. The successful respondent will be able to develop a diagnostic tool that assesses the operational state of each component of a networked system of varying complexity and redundancy following electromagnetic disruption.

The Air Force can provide test facilities (such as an anechoic chamber, GTEM cell, or laboratory space) and a wide range of test and diagnostic equipment (including but not limited to: oscilloscopes, sensors, antennas, network and spectrum analyzers) to the contractor.

PHASE I: Develop a concept and architecture for the diagnostic tool.

PHASE II: Build the diagnostic tool, and demonstrate it for at least two components of a computer system of interest, such as a generic PC and an Ethernet switch.

PHASE III: Phase III efforts would focus on technology transition for dual use in commercial systems as well as specific DoD systems.

REFERENCES:
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2. Agis Iliadis and Kyechong Kim, "Effects of Microwave Interference on MOSFETs, Inverters, and Timer Circuits" (2006).

3. Kyechong Kim, Agis A. Iliadis, and Victor L. Granatstein, "Effects of Microwave Interference on the Operational Parameters of n-Channel Enhancement Mode MOSFET Devices in CMOS Integrated Circuits," Solid-State Electronics 48 [10-11], 1795-1799 (2004).

KEYWORDS: effects, electromagnetic disruption, digital system

AF151-011 TITLE: <u>Tool for Assessing the Recuperation Time from an Electromagnetic Disruption for a Digital System</u>

TECHNOLOGY AREAS: Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: To produce a tool set that can be used to assess the operator response to an electromagnetically triggered disruption of a digital system, to help determine the recovery time to a basic recovery state and full functionality of the system.

DESCRIPTION: The Air Force is moving towards the use of networked commercial off-the-shelf (COTS) electronics for many of its functions, including military operations. Since many of these systems are required to operate in a high electromagnetic field environment, it is critical to understand the potential for electromagnetically triggered disruption (upset) of the system, and to develop an understanding of how long such a disruption might last. Currently there are no good tools to predict the recuperation time leading to a basic or fully functional digital system after a disruption.

The recuperation time for a complex networked digital system involves a number of factors, some technical and some human. An example of the former would be software self-diagnostic and subsequent application restart, the time required to rebuild a corrupted database, or reboot time for a server, while an example of the latter might be the human intervention and time to troubleshoot the system after a problem has been identified. The focus of this effort is specifically on the human aspects of the problem, with a goal to determine bounds on the time required to restore a disrupted system to basic and full functionality. In this context, it will constrain the predicted recuperation time based on system components, complexity, architecture, operator expertise. The concept involves attaching the tool to a running network, with realistic software running and users performing representative tasks, and using it to measure and bound the recuperation time associated with specific system disruptions. The final product includes software, hardware, and other tools and resources to accomplish this goal for which no current solution exits. In coordination with and approval of the Air Force technical point of contact (TPOC), the final product will be demonstrated on a network system, in a suitable environment, using High Power Electromagnetic (HPEM) sources, to disrupt or disable the system. The technical description, utility, and operational details of the deliverables are to be completely documented.

PHASE I: Develop concept and architecture for assessment tool. The tool may consist of multiple hardware modules that can be attached to components of the networked system together with a master control module that monitors the recovery process and records data pertaining to a bounded system recuperation time based on system and operator constraints. Technical description shall be completely documented.

PHASE II: Build and demonstrate assessment tool on a network representative of a command and control system selected in coordination with the TPOC. The system shall include components such as servers, clients, switches, routers, and configured to run representative software applications. An appropriate HPEM source and test environment approved by the TPOC shall be used to disrupt or disable the system under test. Technical and operational details shall be completely documented.

PHASE III: Refine and advance the tool set developed in Phase II and focus on technology transition for dual-use domestic applications to commercial and DoD systems. The technical utility and operational details of the refined assessment tool and its dual use shall be completely documented.

REFERENCES:
1. "Understanding Network Failures in Data Centers: Measurement, Analysis, and Implications," A. Gill, N. Jain & N. Naggapan, 2011, http://research.microsoft.com/en-us/um/people/navendu/papers/sigcomm11netwiser.pdf.

2. http://www.empcommission.org/docs/A2473-EMP_Commission-7MB.pdf.

3. http://www.futurescience.com/emp.html.

KEYWORDS: effects, time out of action, recuperation time

AF151-012 TITLE: <u>Airborne Fuel Cell Prime Power for Weapons Systems</u>

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of

sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop innovative, airworthy, power systems based on fuel cell prime power that are scaleable to levels for directed energy systems with maximum achievable energy densities.

DESCRIPTION: The existing fuel cell state of the art now provides an advantageous source of prime power for most vehicular applications, both laser and microwave, under development at the Air Force Research Laboratory [1]. These efforts should advance the state of the art compared to turbo-generator power generation units, via SWAP and fuel consumption. There are several types of fuel cells; however, the hydrogen fueled PEM (Proton Exchange Membrane) type is probably the most suitable at this time. The DOE has several programs working the development of fuel cells for automotive and other applications. These programs include the logistics of hydrogen fuel production and storage as well as the cells themselves. Based on this work, the time is now for AFRL to get involved and start planning the integration of fuel cell technology to provide the prime power for present and future advanced weapons systems, such as typical GA MQ-9 Reaper unmanned aerial vehicle (UAV) and up to combat aircraft, such as the JSF F-35. Projected burst mode power requirements range from 100kW to1MW average power. The projected energy capability should be traceable to more than 25MJ per mission. The optimum use of fuel cells for pulsed power systems uses the fuel cell to deliver a relatively constant power direct current that is stored in a Li-ion or Li-polymer battery, in combination with power electronics, to provide the high peak pulsed power to the load. An interesting advanced commercial PEM fuel cell rated at 110kW available from Nuvera [1]. Hydrogen storage and logistics problems are also being addressed in terms of existing components and technologies [2,3]. Fuel cells are ideal for typical AFRL pulsed power weapons applications. PEM fuel cells have no start-up time compared to turbo-generator prime power sources. The fuel cell approach advances the state of the arr by the fact that there is essentially no mechanical inertial or electrical inductance that seriously degrades the conventional appraoch of turbo-generators. In missions that require a long stand-by mode a turbo-generator has to be running, no load, at rated speed in order to provide fire power on demand. Typically, a turbine consumes about 70 percent of the full power fuel when running at rated speed and no-load. This obviously results in very high fuel consumption for missions requiring extended ready mode duration. PEM cells in addition to having a higher efficiency, do not consume fuel at no-load, provide fire power on demand from a cold stand-by, and converts the fuel directly into direct current. The SOFC (solid oxide fuel cell) [4] is also a possible candidate for prime power. The SOFC fuel requirement consists has a wide range of acceptable fuel, including JP-8, ethanol, propane, and most hydrocarbons. However, the SOFC operates at a temperature of approximately 800 degrees C and therefore does not have an instantaneous start up time. In some applications the flexible fuel type logistics may be advantageous.

PHASE I: Develop a conceptual design to the PDR level that consists of:
1. Fuel cell prime power, including fuel for one mission
2. Pulsed power energy store with charging interface connecting the fuel cell
3. Thermal management concept for an airborne implementation, not including the thermal management of the pulsed power load

PHASE II: Refine the Phase I conceptual design to the CDR level. Select and procure the basic fuel cell part of the design and interface the control system to operate into a resistive load and verify the performance. Submit a test plan for approval before implementation of the verification testing. The implementation of the design for the pulsed power energy store and modulator is not required for this effort.

PHASE III: Complete the fabrication of the Phase II design to include the pulsed power energy store and modulator and verify operation by test. The modulator is to be designed to interface an application, if such application is available that is consistent with the design.

REFERENCES:
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2. http://www.nuvera.com/index.php/markets/aerospace.

3. http://www1.eere.energy.gov/hydrogenandfuelcells/storage/current_technology.html

4. http://www.nuvera.com/index.php/markets/on-site-hydrogen-generation.

5. https://technology.grc.nasa.gov/documents/auto/Solid-Oxide-Fuel-Cells.pdf.

KEYWORDS: fuel cell prime power, fuel cell APU, air platform prime power, pulse power weapons systems, energy storage, electronic warfare

AF151-013 TITLE: Materials and Designs for Compact High-Voltage Vacuum Insulator Interfaces

TECHNOLOGY AREAS: Weapons

OBJECTIVE: The goal of this effort is to develop a compact and robust high voltage insulator design that could be used at the vacuum interface between the coaxial output of a pulsed power driver and its vacuum load.

DESCRIPTION: As directed energy systems have advanced in capability, development teams have also worked to reduce the size of these systems in order to make them deployable on various-sized platforms. For a variety of reasons, the pulsed power driver is often one of the largest components in a directed energy system, and so there have been a number of efforts in recent years devoted to shrinking their size. A key component of the driver with which to contend is the insulating structure, or bushing, around its output terminal, which also serves as an interface between the driver environment and that of the load it is driving (e.g., the driver may be immersed in oil or a high-pressure insulating gas, while in most cases the load is under vacuum). Such loads may include high power microwave (HPM) sources, particle accelerators, or other vacuum electronic devices.

High voltage vacuum insulators in general have been a topic of research for many decades, as they are used in many scientific and engineering applications. The design of such insulators is complicated by the fact that electrical breakdown can be induced across the insulator surface by more than one mechanism [1, 2], each of which must be mitigated to allow the voltage capabilities of the insulator to be increased. Increasing insulator size to enable greater electrode separation reduces the field stresses on the insulator and most often mitigates the breakdown problem, however doing so runs counter to efforts aimed at reducing overall system size. It therefore is necessary to engineer the geometry of the insulator, including positions of triple points, and to carefully choose the insulator material composition so as to both maintain compact size and suppress the growth of breakdown mechanisms that are present with high electric field stresses.

To remain on the forefront of compact pulsed power driver development, the Air Force Research Laboratory desires to push the state of the art of high voltage insulators such that greater field stresses can be placed across smaller coaxial insulators for longer pulse durations. Recent publications describing the state of the art for insulator development report field stresses of ~300 kV/cm being sustained for 100 nanoseconds across small samples (0.5–1.0 cm) of high gradient layered insulators [3]; these field stresses are several times the threshold for surface breakdown across conventionally designed insulators (50 kV/cm [4]). We have an interest in exploring the feasibility of further increasing sustained field stresses by at least 50 percent (to 450 kV/cm) above these reported values, across insulators having operationally relevant sizes (several cm), for this same time scale and/or of increasing the duration of the applied fields by 1 or 2 orders of magnitude (to microseconds or 10s of microseconds) while still avoiding breakdown.

To accommodate the coaxial electrode arrangement, the insulator may be either radially or axially oriented, or some variant in between. The first provides the most compact arrangement but has the highest field stresses (located where the center electrode passes through the insulator); the second can can provide a more uniform field distribution across the insulator with possibly greater distances between the high voltage and ground than in the radial orientation but at the cost of an increased volume required for the insulator. The last configuration seeks a compromise between the two.

PHASE I: Develop a design for a compact coaxial vacuum interface insulator using state-of-the-art insulator materials suitable for vacuum. Through modeling, examine field stresses predicted on the insulator and iterate the design so as to maximize applied center conductor voltage. A Preliminary Design Review will be held at the completion of the Phase I work to discuss the design and the modeling results

PHASE II: Using the dimensions and other relevant design specifications for a pulsed power driver and vacuum test load provided by the Air Force Research Laboratory, develop a finalized (full-scale) coaxial vacuum insulator design. Voltages on the center conductor will be 600 ~ 750 kV. Following a Critical Design Review, fabricate the proposed coaxial insulator and characterize its voltage hold-off capabilities using the previously-identified pulsed power driver and vacuum test load.

PHASE III: Perform characterization tests with the interface insulator in a relevant operating environment, i.e., with the vacuum test load replaced with an HPM source, the electron gun of a particle accelerator, or other relevant vacuum electronic device.

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1. A. A. Avdienko and M. D. Malev, “Flashover in Vacuum,” Vacuum 27, pp 643-651, (1977).

2. H. C. Miller, “Flashover of Insulators in Vacuum,” IEEE Trans. Electr. Insul. 28, pp. 512-527, (1993).

3. J. R. Harris, D. Blackfield, G. J. Caporaso, Y. –J. Chen, S. Hawkins, M. Kendig, B. Poole, D. M. Sanders, M. Krogh, and J. E. Managan, “Vacuum Insulator Development for the Dielectric Wall Accelerator,” J. Appl. Phys. 104, 023301, (2008).

4. S. E. Sampayan, G. J Caporaso, D. M. Sanders, R. D. Stoddard, D. O. Trimble, J. Elizondo, M. L. Krogh, and T. F. Wieskamp, “High-Performance Insulator Structures for Accelerator Applications,” Proc. 1997 Particle Accelerator Conference, 12-16 May 1997, Vancouver, B.C., Canada, pp 1308-1310.

KEYWORDS: insulator surface tracking, surface flashover of insulators, vacuum insulator materials, high voltage insulators

AF151-014 TITLE: Breakdown Resistant Materials for HPM Sources

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Design, via ab initio numerical modeling, breakdown resistant materials with high field emission (FE) and desorption thresholds (E field >10^-2 V/Å) at L-band and low emission threshold cathode materials with high current for lower voltages (~300kV).

DESCRIPTION: Air Force High Power Microwave (HPM) system performance is limited by material degradation in the presence of high electromagnetic stress environments. The next generation of HPM sources will require the input and generation of tens of Giga-Watts of electromagnetic power within a space that is small enough to be placed on an airborne platform or other compact platform. Current HPM systems are incapable of producing or withstanding the high electrical current densities that such future systems would require. Additionally vacuum breakdown within the compact source itself limits the output power that the system can produce. Advancing to the next generation of HPM sources will require novel materials that are capable of conducting high current without collapsing under Joule heating and without suffering breakdown. Novel materials designed to maximize (for HPM source cathodes) or minimize (for breakdown mitigation) emission where necessary may mitigate these obstacles and provide a means to obtain higher HPM power for compact sources.

Innovative design of cathode materials capable of withstanding high electrical current density emission are necessary to meet the demands that future HPM systems would require. Such a cathode would be capable of conducting over 200 µA per fiber with cathode current densities of 3000 A/cm2 for 600 ns pulse or 1000 A/cm2 DC as a final goal, without degradation or destruction due to Joule heating. Moreover the cathode material and the HPM system material must be capable of producing high currents as well as mitigate neutral outgassing and secondary electron emission while under high electromagnetic stress. The HPM material must have a higher threshold for breakdown where appropriate.

Numerically derived candidate materials are sought to meet the demands of next-generation HPM sources, Ab Initio numerical modeling of candidate materials in a high electromagnetic stress environment is now possible due to advances in atomistic modeling and the availability of large multi-core parallel computing architecture. Time Dependent-Density Functional Theory (TD-DFT) and standard Density Functional Theory (DFT) based algorithms represent the state of the art for numerical solutions of the quantum many body problem. These methods will allow for a detailed understanding of the emission process in HPM sources. The Fowler-Nordheim relation, derived in 1927, for planar geometry, non-interacting electrons, and no accounting for electronic structure, represents our best understanding of field emission however with TD-DFT and DFT we can now move beyond this. Where field emission is desired (cathode in an HPM source) we seek materials and/or material configurations that will lower the voltage threshold for field emission and increase field emission current magnitude. Where emission is unwanted (an anode for an HPM source) we seek materials with high thresholds for electron stimulated desorption (ESD), field emission, secondary electron emission (SEE). These emission processes yield a plasma in the HPM source resulting in pulse shortening and thus degradation of HPM source operation.

TD-DFT has recently been used to examine the phenomena of field emission from Carbon Nanotubes (CNT) resulting in the identification of adsorbates that significantly enhance field emission current. Potential Energy Surfaces (PES) used to describe the interaction between a surface and a molecule may be derived using DFT. The PES may then be used to determine forces acting on a molecule and thus describe the desorption process. The goal here is the virtual prototyping of materials with desired properties for next-generation HPM sources.

PHASE I: Utilize numerical materials design for cathodes to identify novel materials with low field emission thresholds and high field emission current. Perform analysis of materials (CNTs for example) to identify variants that may extend field emission enhancement or lower emission threshold. Focus is on field emission current enhancement.

PHASE II: Identify materials with high thresholds for ESD, and SEE via DFT or other Ab Initio technique using PES approach or alternative. Focus is on emission mitigation. Extend above research to detail interaction effects among elements of the material in bulk as well as surface effects. Identify the effects of variation in the material on field, ESD SEE emission properties.

PHASE III: Military Use: Enables compact high power electronic systems for electronic attack. Commercial Use: Broad use for electronics. For example, FE degrades electronic device operation. Voltage leakage yields energy loss and short battery life. Emission control advances mitigate this issue.

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KEYWORDS: density functional theory calculations, time-dependent density functional theory, field emission current, Fowler-Nordheim current, electron stimulated desorption, neutral outgassing, potential energy surface, pulse shortening, dissociative scattering

AF151-015 TITLE: Transforming Cyber Data into Human-Centered Visualizations

TECHNOLOGY AREAS: Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Determine innovative ways to transform cyber data into visual representations based on the cognitive needs of cyber operators; design and evaluate visual representations to determine operator effectiveness in performing cyber tasks.

DESCRIPTION: Effective cyber operations, both on the offensive and defensive sides, are essential for conducting Air Force missions. Cyber operators, who may be new to this domain because of the high demand this need has placed on the Air Force workforce, find themselves challenged on two fronts. First, they must try to make sense of the vast amounts of data which are being presented to them, often in raw format. Cyber operators are drowning in data that they cannot effectively understand, manage, and use to make sound decisions. Second, they are constantly trying to learn new tools that are being offered to them, each independent from one another with unique features, rules, syntax, interfaces, interaction techniques, etc. The Air Force Cyber Vision 2025 (Maybury, 2012) enumerates four “Focused, Enabling S&T Areas,” one of which is “Optimize Human-Machine Systems,” and the near-term goal is summarized as providing “Advanced Situational Awareness for Cyber Operators.” Similarly, Air Force Space Command's Cyber Superiority S&T Guidance states that “for effective knowledge operations, technologies are needed to vastly improve man-machine interfaces to speed the assimilation of data and the development of actionable information and courses of action for cyber operators.” Based on these stated needs, the goal of this topic is to find innovative ways to optimize the assimilation, transformation, and visual presentation of cyber data in ways that support the operators’ cognitive capabilities so they can effectively do their job.

The cyber domain has the unique characteristic that the resources necessary for superiority in the domain are not aircraft and airfields as in the air domain, but highly trained and competent personnel (Bryant, 2013). This statement boldly places the success or failure of cyber superiority on the human factor - in the hands of the cyber operator. Therefore, it is imperative that the information displays with which these operators interact are designed for effective human use.

Specifically, this process must begin with a thorough understanding of the cyber analysts’ job (goals, tasks, objectives, information needed, decision processes, etc.), so the design team can determine the cognitive processes that need to be supported when these operators are performing their tasks. The design team will use this knowledge to transform data and design visualizations accordingly. Some visualization techniques that may be considered are parallel coordinates, tree maps, recurrence plots, theme rivers, and/or any new or innovatively used existing graphical techniques. Visualizations can be static or interactive to provide multiple levels of information - overview, zoom/filter, details on demand (Shneiderman, 1996). Visualizations may also include innovative ways to apply visualization techniques from other domains to the cyber data problem (i.e., determining how to apply text visualization techniques such as tag clouds to network data). Iterative prototyping and user feedback should be part of the design process to ensure the visualizations meet the user’s needs. A multi-disciplinary team will be necessary to perform the tasks in this effort.

PHASE I: Investigate various ways to mathematically and/or statistically transform raw cyber data to create visualizations that support specific cyber analysts' tasks. The products from this phase should include description of specific tasks, raw data necessary to perform the tasks, transformations of the data, the visualizations created as a result of the transformations.

PHASE II: This phase includes the integration of the visualizations in an operator interface and human-in-the-loop testing of the effectiveness of the visualizations compared to a baseline representation of the data with cyber operators. Deliverables include visualization/interface software, use cases/tasks for data collection, test plans of experimental design and metrics, data, data analysis, and documentation of the results of the studies.

PHASE III: Potential Air Force Transition: Air Force cyber mission platforms.
Potential Commercial Transitions: Financial institutions, power and electric companies, big box companies, and third-party Cyber Network Defense Service Providers.

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KEYWORDS: user-centered visualization design, human factors engineering design process, visualization techniques, cyber security, cyber defense, cyber analysts

AF151-016 TITLE: <u>Improved Version of Solid State Night Vision Sensor</u>

TECHNOLOGY AREAS: Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop an improved version of a compact, high performance and solid state night vision sensor that will replace the image intensifier tube in the current night vision goggles (NVGs). It should have digital output and cover a wider spectral range.

DESCRIPTION: To support night combat missions throughout the world and meet the requirements for warfighter readiness and mission performance, a new generation of head-mounted digital night-vision technology is envisioned. The critical, limiting factor of this technology is the sensor. Current sensor technology for head-mounted systems cannot provide the same performance, particularly at the lowest light levels, as compared to the latest image intensification technology. A high performance sensor could be integrated into a head-mounted night-vision optical system to truly provide a digital capability.

The limitations of the present analog approach (i.e., image-intensifier-based night-vision goggles) are the: size and weight, cost of the image intensifier tube, lack of processing capability, limited image transmission capability for sharing the visual image, limited imagery/symbology insertion capability, limited ways to obtain a polychromatic display, and limited spectrum.

Specific requirements for this effort are: light sensitivity, noise resolution (sensor element size), format size, total number of sensor elements, size, weight, power consumption, and cost shall be equivalent to or better than the current generation of image intensifier tube. Desired spectral sensitivity range should be visible, near infrared, and short wave infrared (up to 2 microns).

Recent efforts to develop such a sensor have in general been successful using different approaches. However, some limitations still exist such as resolution, dark current and spectral range. The optimum resolution should be 2048 x 1536 and threshold resolution should be 1024 x 768. The optimum value of dark current should be 1 electron/sec/pixel and the threshold value should be 10 electron/sec./pixel. The spectral range is expected to be 04 to 2 micron.

PHASE I: This phase shall require the vendor to design and demonstrate the technical feasibility of an innovative approach to the solid state digital night vision sensor technology that will cover the spectral range from 0.4 to 2.0 microns while reducing the size, weight, and overall power requirements of the NVGs.

PHASE II: Four prototypes of the optimized design shall be fabricated, demonstrated, and delivered for incorporation into Gen III type head-mounted digital night-vision system for both laboratory testing and field demonstrations.

PHASE III: Military applications: Pilots, loadmasters, special operation ground personnel, base security. Commercial application: Law enforcement, border patrol, fire-fighting, security, and crop dusting. Under certain conditions, the commercial pilots may also benefit from implementation of such technology.

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5. D. Kent and J. Jewell (1995). Lightweight helmet mounted night vision and FLIR imagery display systems. Helmet- and head-mounted displays and symbology design requirements II; Bellingham, WA, Proceedings of the Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Vol. 2465), Orlando, FL, Apr 18-19, 1995, (A95-33965 08-54), p. 68-80.

KEYWORDS: night vision, image intensification, solid state sensor, near infrared, short wave infrared, spectral range, high performance

AF151-017 TITLE: <u>Cockpit Passive Optical Helmet Tracker (CPOHT)</u>

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop cockpit helmet tracker based on passive sensors together with optical feature recognition and image processing algorithms usable for all helmets/aircraft. Approach should not use magnetic sensors, cockpit mapping, or active helmet emitters.

DESCRIPTION: Fighter pilot head-mounted avionics systems currently employ helmet trackers based on magnetic or active optical sensing techniques to detect the instantaneous helmet orientation with the cockpit. This detection enables symbology or synthetic imagery to be mapped from the aircraft coordinate system to the helmet coordinate system for presentation on the helmet mounted display (HMD) so that it is perceived by the pilot to register accurately to the real-world outside the aircraft. The threshold (objective) latency for this entire detection and coordinate transform process is <16 ms (<5 ms), with <3.3 ms (< 1 ms) available to the tracker update step. Magnetic trackers currently fielded in e.g. the Joint Helmet Mounted Cueing System (JHMCS) require each cockpit to be mapped separately in a time-intensive procedure with special equipment, and then re-mapped frequently whenever any change is made to that particular cockpit. Active optical trackers as used in the Eurofighter Typhon HMD system require a flashing infrared light-emitting diode array (IRLEDA) to be integrated into the outside layer of the helmet together with multiple cockpit-mounted sensors to detect their emissions for processing. Integration of active optical tracker components (OATC) into the helmet ties the tracker technology development to other digital HMD components maturing on separate timelines, prevents easy implementation for other helmet shell designs from other manufacturers, and impedes affordable retrofit to all air fleets. Both the IRLEDA and OATC approaches add head supported weight to the HMD system. Multiple imaging and processing techniques have recently evolved that enable a cockpit passive optical helmet tracker (CPOHT) technology to be developed to determine helmet position and orientation with threshold accuracy of 0.1-deg (17 mrad) forward and 0.25-deg (44 mrad) elsewhere. Potential advanced, passive optical cockpit helmet tracking system include, but are not limited to, (a) an array of unique Quick Response Code (QR code) stickers applied to any helmet and interrogated via a cockpit-mounted camera(s) and (b) video image processing based on pre-processed outputs from cameras mounted on the helmet and/or in the cockpit. The CPOHT design must (a) consider tactical cockpit space-weight-ergonomics-power-performance-integration (SWEPPI) constraints, (b) accommodate HMD night vision goggles and laser protection eyewear, and (c) enable installation with minimal aircraft modification. The CPOHT design must also have minimal impact on the helmet mass properties (total weight and net moment arm). Government Furnished Equipment (GFE) and government facilities are not required. Standard aviation helments (e.g., HGU-55/P or HGU-56/P) are available for purchase.

PHASE I: Design CPOHT system that can be affordably implemented in any cockpit and on all helmet types. Approach should work for standard aviation helmets (e.g., HGU-55/P, HGU-56/P) without the addition of any electronics, optics, or emitters. Approach may involve stickers (such as QR codes) placed on the shell along with a cockpit-mounted video capture/recognition/processing system.

PHASE II: Fabricate an engineering prototype CPOHT. Develop a test plan. Perform threshold (objective) test and evaluation of the engineering prototype in an avionics systems integration laboratory (flying testbed aircraft). Demonstrate the prototype meets the key requirements for a combat aircraft head tracker system. Develop roadmap to mature the technology for evaluation in a tactical aircraft flight test and for Phase III commercial uses. Develop a bill of materials for a pre-production CPOHT kit.

PHASE III: Develop CPOHT pre-production product and conduct tactical aircraft flight testing. Address potential application to dismounts and command center operators. Develop commercial CPOHT product for an application such as commercial aviation, training, wearable information systems, and entertainment.

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KEYWORDS: Cockpit Passive Optical Helmet Tracker, CPOHT, alternative night/day imaging technology, ANIT, quick response code, QRC, optical metrology, image processing, avionics, systems integration laboratory

AF151-018 TITLE: 1360 Digital Panoramic Night Vision Goggle (DPNVG)

TECHNOLOGY AREAS: Air Platform

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OBJECTIVE: Develop clip-on, helmet-mounted digital panoramic wide field-of-view (WFOV) night vision goggle (NVG) having cueing functionality and demonstrate its safety and effectiveness in an avionics system integration laboratory or flight testbed aircraft.

DESCRIPTION: A WFOV NVG with integrated symbol overlay capability with acceptable mass properties (total head-born weight and moment of inertia) is sought. Cueing is a core requirement for the symbology. Currently fielded night vision systems perform imaging (sensing, processing, display) in an analog device comprising a low work function phosphor, microchannel plate, fiber-optic bundle, and visible (green) phosphor. Examples include AN/AVS-9 and AN/AVS-10. These current systems, based on third Generation III (Gen-III) near-infrared (NIR) vacuum tube technology, are not digital. Digital sensors are beginning to appear that may match the scene image resolution provided by a Gen-III analog NIR tube, which is about 5 Mpx in a 40-degree conical field-of-view (FOV). Furthermore, these digital sensors can be sensitive to multiple bands: visible (VIS 0.4-0.7 µm), near infrared (NIR, 0.7-0.9µm), and shortwave infrared (SWIR, 0.9-1.8 µm), or to all three. Digital image sensors, processors, and algorithms are now available that can handle up to 1600x1200 pixels at 60 Hz, with a near-term path to 2000x2000 pixels at 60 Hz. Digital sensor technology candidates for DPNVG include the Intevac Silicon Imagine Engine (ISIE) devices (e.g., the post-ManTech 1600x1200 ISIE 11 and developmental ISIE4000), the UTC Aerospace Systems SWIR and NIR-SWIR cameras (e.g., 1280x1024 GA1280JSX-12.5-60 ENC), and commercial CMOS cameras with NIR filter removed to provide color VIS plus NIR performance. The in-helmet portion of the processing load can be based current and emerging computer graphics and processor chips. Digital microdisplays have appeared in multiple technologies--reflective liquid crystal on silicon (LCoS), transmissive active matrix liquid crystal display (AMLCD), active matrix organic light emitting diode (AMOLED), and digital micromirro devices (DMD)--with pixel formats up to so-called ultra high definition television 1 (UHDTV1) standard 3840x2160 at 60 Hz (8 Mpx, aka 4K). UDHTV2 microdisplays with pixel resolution of 7680x4320 (32 Mpx, aka 8K) are in development. Higher frame rates of 96 to 192 Hz may be required from the digital device train (sensor-processor-display) to match, from a perceptual perspective, a sufficient part of the currently fielded temporal performance of Gen-III tubes, whos effective frame rate is about 1600 Hz. Similarly, current sensor outputs are typically 14b but available displays handle just 8b, so that improved dynamic range display devices are desired to avoid loosing sensor-captured scene contrast information. The maturity of the digital imaging components for sensing, processing, and display is now sufficient, however, to initiate innovation towards a purely digital near-eye visualization system to replace the analog vacuum tube technology now used in fielded paranomic night vision equipment. These digital devices enable capabilities not available to the currently fielded analog technologies, such as image processing, fusion, recording, communication to/from the helmet system. Space, weight, ergonomics, power, performance, and integration (SWEPPI) must all be addressed in the helmet mounted design. The DPNVG must be designed to meet all safety-of-flight criteria including maximum head borne weight, center-of-gravity, and ejection wind-blast. Tiling of multiple devices (sensors, processors, displays) and partitioning of processing between the helmet and cockpit-interface box should permit design and fabrication of a DPNVG with threshold (objective) performance of near 20x20 acuity with WFOV 60x30-deg (120x50-deg), frame rate 60 Hz (96 Hz), dynamic range 8b (14b) and night-only (day/night) operation.

PHASE I: Design tactical helmet-mounted DPNVG with acceptable mass properties that integrates cueing and night vision. Threshold (objective) frame rate of 60 Hz (96 Hz) and horizontal x vertical field-of-view of 60x30-deg (110x40-deg) with resolution equivalent AN/AVS-10 or better are sought. Design should address day/night operation potential and all-source fusion of on/off helmet data and video inputs.

PHASE II: Fabricate, test, demonstrate and deliver one DPNVG prototype. Perform test and evaluation experiments in a threshold (objective) environment comprising an avionics system integration laboratory (testbed aircraft in flight). Demonstrate DPNVG night vision capabilities compared to current analog in-line night vision equipment based on Gen-III tubes and current weapon cueing capabilities in current day-only systems. Develop reference design for affordable production and provide bill of materials.

PHASE III: Fabricate flight-worthy pre-production DPNVG. Demonstrate safety and effectiveness in tactical aircraft operations. Develop plan for similar helmet-integrated visualization systems for dismounted special operators, ground vehicle driver, and applications for homeland security and law enforcement.

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KEYWORDS: Digital Panoramic Night Vision System, DPNVG, night vision goggles, AN/AVS-9, Joint Helmet Mounted Cueing System, JHMCS, near-eye visualization system, digital replacements for analog sensor and display tubes, tactical cockpit, day/night operations

AF151-019 TITLE: Optimized Information Display for Tactical Air Control Party

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: The technologies deployed with TACPs need to optimize ergonomics and functionality and minimize physiological effects. A new TACP information display configuration is needed to ensure Air Force weapons are optimally employed in the battlespace.

DESCRIPTION: U.S. Air Force Tactical Air Control Party (TACP) members deploy with U.S. Army Rangers, Special Forces, U.S. Navy SEALs, and Army maneuver units as joint terminal air controllers (JTACs) to provide a command and control (C2) link for close air support (CAS), airlift, surveillance/reconnaissance missions. The actions performed by TACPs reduce the kill chain decision time and the potential for fratricide and collateral damage in civilian-occupied areas. Display and information processing technologies are progressing rapidly, creating new opportunities in wearable displays. This effort will focus on developing a combined, optimized visual information display environment for TACP operations. It is intended to develop configurations that improve ergonomics, minimize short and long term physiological effects (eye strain, radiation bioeffects, etc.) and the overall weight and power requirement.

The purpose of the TACP-modernization (TACP-M) program is to provide net-centric data communications, battlespace awareness, and targeting capabilities to TACPs operating in operations centers, vehicles, and while conducting dismounted operations. Data communications, including streaming video, reduce reliance on voice transmissions and enable machine-to-machine data exchange between TACPs, JTACs and command and control (C2) nodes, close air support (CAS) aircraft, Army units and other TACP, JTAC units. Current displays, including, hand-held, chest and head mounted have significant limitations including poor daylight readability, poor nighttime light discipline, occluded vision, reduced situational awareness, induced fatigue due to constant near-far visual focus transitions and suboptimal posture.

This effort will determine what physical effects may be caused by long periods of exposure to small (5”-7”) display devices worn in a chest mounted configuration while in combat conditions. Factors that should be considered include, but not limited to, day/night time viewing, screen resolution, focal points, screen brightness, and electromagnetic radiation exposure. Additionally the same effects should be analyzed utilizing a helmet mounted heads-up display (HUD) (for example, Google-Glass, wrist-mounted, flexible displays), fixed, or detachable displays in lieu of or in conjunction with the chest mounted display. Issues will include the operational issues such as directed attention, visual accommodation, mobility (speed), perspiration, various body posture physical maneuvers and the effects of intense heat, bright sunlight, rain, water immersion, mud, and sand.

A philosophy of display information format will be developed based on the types and priority of information to be conveyed, responded to, and interacted with. This is based on what you need to do, discussion (what are you doing, what do I need to do), search for the information, calculate, interpret, comprehend, and communicate perspective and actions. As a result of the analysis to determine the information interpretation, manipulation, and conveyance requirements; the physiological impacts, of both short- and long-term use of potential technologies; an optimal information display configuration will be created.

PHASE I: Review TACP, JTAC information requirements, current display deficiencies and equipment integration constraints. Review ergonomic principals for portable displays and survey current state of the art display technologies. Conduct a comprehensive analysis of display technology trade space and design an optimal TACP, JTAC visual display.

PHASE II: Build, evaluate, demonstrate and deliver rapid prototype of the design from Phase I.

PHASE III: Rugged, high performance, wearable information systems are widely used by the law enforcement, agriculture, environmental science, construction and shipping workforce.

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KEYWORDS: TACP, JTAC, display, physiology

AF151-020 TITLE: F-35 Display Improvement

TECHNOLOGY AREAS: Air Platform

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OBJECTIVE: Develop displays for F-35 that have higher refresh rate, resolution, and brightness, with improved touch screens, optimized power/thermal management, and lower weight.

DESCRIPTION: Cockpit displays for fighters have performance requirements far beyond the commercial-state-of-the-art. Full sunlight readability and night vision compatibility are mandatory but not found in commercial offerings. Drive electronics to achieve a minimum 40:000:1 dimming range and ultra-high reliability under extreme environmental conditions are needed but unavailable in mass production products. The technical challenges include leveraging on-going revolutions in high-efficiency lighting and additive manufacturing to meet this combat cockpit need.

The goal of this F-35 Display Technology Improvement program is identify, develop, and integrate technologies to achieve a threshold (objective) 84 Hz (108 Hz) update rate, 8 Mpx (32 Mpx) image resolution, 600 fL (1200 fL) sustained day luminance, 0.01 fL (0.001 fL) night luminance with electro-optical emissions compatible with digital and analog helmet/cockpit-mounted cameras, advanced touch screens compatible with flight-gloved hands, 2X (4X) less net power via higher efficiency materials and energy re-cycling, advanced heat transfer and storage materials, lower weight substrates and structural housings. The main focus is on improvements for the 20x8-in. primary multifunction display that can demonstrate life-cycle cost (LCC) or warfighter effectiveness improvements the would justify switching the from the current circa 2004 AMLCD designs to incorporate manufacturing technology improvements available in circa 2016 components.

Teaming with prime contractors for transition analysis and support is encouraged. Affordability and availability should continue to be addressed by using commercial fabrication facilities to fabricate military-unique designs.

Flat panel technologies revolutionized cockpits during the 1990s and were the basis for an epochal shift from electromechanical and cathode-ray tube flight instruments to the avionics-grade sunlight-readable, reliable, active matrix liquid crystal displays (AMLCDs) that now dominate crew station design. Large-area AMLCDs have enabled the realization, in the F-35 cockpit, of the combat advantage demonstrated in the 1988-1992 AFRL ATD entitled Panoramic Cockpit Controls and Displays (PCCADS). PCCADS demonstrated that a large area, integrated main instrument panel display and a digital day/night vision/cueing system would increase combat effectiveness by 45 percent.

Current displays have limitations that have been accepted to affordably achieve threshold levels of pilot-vehicle interfaces. Technology obsolescence problems and improved performance opportunities require new innovations.

Improvements in power-hungry AMLCD technologies are possible for both the main panel (currently dominated by a 20x8-in. AMLCD driven as two 1280x1024 pixel windows) and the helmet system. The see-through helmet-mounted display (HMD) design uses miniature AMLCDs reflected off the visor using classical optics. Significant advances have been made, since the time of F-35 cockpit design freeze, for both the large-area direct-view 20x8-in. display and the miniature flat panels in the HMD.The 20x8-in display and the HMD are now both over 4X less resolution compared to the current state of the art. Higher pixel densities with the same or less power are possible to provide more detailed situational awareness displays. Substrates are lighter yet stronger. And new flat panel technologies, such as active matrix organic emitting diode (AMOLED) and electrophoretic, are on the verge of becoming competitive with AMLCD for avionics cockpit applications. Other HMD component technology improvements are emerging from DoD programs like the AFRL Alternative Night/Day Imaging Technologies (ANIT) program.

PHASE I: Design displays in form-factors for F-35 that weigh less, incorporate improved touch/gesture control interface, optimize power/thermal management, and have higher refresh rate, resolution, luminance. Perform LCC and pilot-effectiveness analyses to determine value of improvements. Develop roadmap for feature introduction and initial technology transition plan.

PHASE II: Fabricate and test prototype displays in the form-factor required by F-35 that weighs less, incorporates a improved touch/gesture control interface, optimizes power/thermal management, and has higher refresh rate, resolution, and luminance. Assess production and reliable sourcing issues throughout the vendor chain involved (AMLCD fabs, system integration facilities, labs for testing to combat avionics performance requirements). Update transition plan and life cycle cost analysis.

PHASE III: Assess DoD market for F-35 new/replacement displays and for other aircraft. Develop a detailed Air Force Human System Integration Plan. Refine design from Phase II prototype into a production design. Establish reliable supply chain and supply chain management system. Fabricate production displays.

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KEYWORDS: avionics displays, panoramic cockpit, tablets, wearables, flat panels, AMLCD, AMOLED, advanced substrates, LED backlight

AF151-021 TITLE: <u>Full-Scale Near-Field Acoustic Holography for Reduction of Annoyance and Disturbance</u>

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Measure the characteristics of jet noise sources from full-scale military aircraft, such as strength, distribution, and noise radiation properties; how they relate to annoyance/disturbance; and possible methods for the reduction of those parameters.

DESCRIPTION: Near-field Acoustic Holography (NAH) and/or beam forming techniques can be used to measure and describe the acoustic field emitted by a source. For example, the jet plume of the F-35 is a large, hot, distributed noise source with high sound pressure levels. The measurement, analysis, and description of the noise sources, their relative intensities, frequency content, spatial location, shock characteristics, shock levels, and the associated acoustic radiation properties are important parameters in describing the factors associated with potential community annoyance. This effort will combine physical acoustics and objective measures of noise emissions with the subjective responses of human listeners to the radiated/propagated noise. The effort will require extensive analysis of measured noise data bases, collection and analysis of realized noise in communities during aircraft operations, and collection and analysis of human responses both in community and laboratory settings. New noise metrics may be developed and proposed which correlate the noise characteristics with the human responses. A limited data package will be provided by the government to award winners.

PHASE I: The initial effort will focus on a review of current noise metrics, existing aircraft noise databases in both the time and frequency domains, and define any requirements for additional noise measurements, both in test and community settings. Additionally, an analysis of the cost-benefit of using near-field acoustic holography and acoustic beam-forming shall be conducted and reported.

PHASE II: The Phase II effort will execute the detailed analysis of the aircraft noise, identifying at least, but not limited to, the temporal and spectral characteristics of the noise in both the near-field and far-field, i.e., community. Noise samples shall be prepared isolating each characteristic. The human listening studies will be conducted to identify the specific characteristics of the noise. A metric shall be proposed and validated which correlates the noise parameters with human responses.

PHASE III: Analysis for jet noise reduction shall be conducted to identify potential target areas for reducing annoyance and disturbance. A cost/benefit analysis of the application of this noise reduction shall be conducted relative to sales and operations of aircraft domestically and internationally.

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KEYWORDS: aircraft noise, NAH, beam-forming, noise metrics, community noise, near-field acoustic holography

AF151-022 TITLE: Realistic Micro-structured Devices to Mimic Organs for In Vitro Aerospace Toxicology

TECHNOLOGY AREAS: Human Systems

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OBJECTIVE: The objective of this work is to develop unique approaches for fabricating micro-structures incorporating shear flow and mechanical flexure simulating whole organs for in vitro toxicology.

DESCRIPTION: Man-made nanomaterials (NMs) are being applied in many aerospace technologies, and the health risks associated with unintentional exposure remain a foremost concern of their pervasive use [1]. Further, particulate matter (PM) and chemicals are released during various aerospace processes, such as jet fuel combustion and practices where materials are burned or detonated. The toxicity of individual NMs, incidental PM and chemical species, in addition to particulate/chemical mixtures are critical to understand for both protecting military personnel and advancing aerospace technologies. Currently, standard in vitro models do not represent the complexity of in vivo conditions [2,3]. Due to the requirement to replace in vivo models to address high cost and ethical concerns, dynamic in vitro models incorporating shear flow and mechanical flexure simulating whole organs are critical. Progress has been made towards this end, such as the development of the lung-on-a-chip model [4]. Advantages of this model is that the chip is optically transparent, allowing for cellular imaging-based endpoints, and has a high elasticity, allowing for mechanical flexure to simulate breathing. There are also drawbacks to the current organ-on-a-chip models. They are limited by traditional fabrication approaches and polymer properties. The polymer commonly used to fabricate the chips, polydimethylsiloxane, suffers from chemical incompatibility. For example, it swells when exposed to chemicals of key concern in aerospace applications, such as hexane and toluene [5]. Therefore, further developments are required in order to improve the complexity of in vitro investigations to support aerospace toxicology. The membrane thickness using traditional organ-on-a-chip approaches does not closely mimic many in vivo membranes. One models of top interest for aerospace toxicology is the blood air barrier in the pulmonary region of the lung. The membrane thickness of the basement membrane in the blood gas barrier is on the order of 0.05 microns, and the thickness of the blood gas barrier in the human lung is 0.2 microns [6]. However, elastic membranes demonstrated in published organ-on-a-chip models are limited to about 10 microns [4]. In addition to thickness, the surface area of the membrane should also be sufficient to allow for enough cells to be grown while remaining within the limits for typical biochemical assays (= 0.2 cm2). The key phases of the project will include (1) design a novel fabrication approach and prototype for a micro-structure device incorporating shear flow and mechanical manipulation, (2) validate the prototype to reproduce whole organ responses to insult or toxic exposures, and (3) incorporate the device into an instrument for producing cyclic mechanical stimulation media perfusion and controlled cell culture conditions. Convenience and aesthetics should be considered at all phases for proper and proficient use. The impact of this technology is to reduce the use of animal models for toxicity testing, thus reducing cost and ethical concerns and increasing throughput.

PHASE I: Design novel fabrication approach and prototype for a micro-structure device incorporating shear flow mechanical flexure and aerosol exposure. Materials should be compatible with standard sterilization techniques, living cells and a range of chemicals. Membranes for growing cells must be porous, elastic and thickness must represent physiological conditions. Be robust for repeated use or low cost.

PHASE II: Following prototype development, the device will be validated for the ability to generate reproducible in vitro data that are representative of in vivo conditions. Examples: any known biological response including acute stress responses and early indicators for chronic conditions to NMs, PM or chemical exposure. Demonstrate biological response of each of the following in aerosol form: PM in the range of 10-1000 nm and chemicals including volatile, semivolatile, particulates/chemical mixture.

PHASE III: Advanced features will be incorporated into the design such as ability to be used for highthroughput. Deliverable will be an instrument where microstructure devices are tested. The instrument should incorporate the ability for mechanical flexure, aerosol, shear flow, standard cell culture condition.

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KEYWORDS: nanomaterials, NMs, micro-structure devices, organ on chip, aerospace toxicology

AF151-023 TITLE: Breathing Air Quality Sensor (BAQS) for High Performance Aircraft

TECHNOLOGY AREAS: Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a miniaturized, orthogonal (i.e., multi-modal) sensor system to detect aircraft breathing air contaminants in flight.

DESCRIPTION: Knowledge gaps exist in the molecular characterization of the operational environments faced by today's airmen. As an example, in 2011, the entire F-22 fleet was grounded for nearly five months due to a series of incidents where pilots had experienced symptoms such as shortness of breath, disorientation, confusion, and headache with no clear cause identified. This led to a series of formal investigations that identified the need to improve our analytical toolset and understanding of the environments encountered in the F22A Raptor and other high performance aircraft, and their effects on the humans operating them.

Modern high performance aircraft, such as the F22A, utilize engine bleed air filtered through an onboard oxygen generating systems to provide the oxygen supply for air crew. The OBOGS (On-Board Oxygen Generating System) uses a molecular sieve to concentrate oxygen in pressurized air from the turbine engine compressor on a schedule associated with aircraft altitude in order to compensate for the decrease in oxygen partial pressure and to protect the pilot against rapid decompression. Investigations conducted by the Air Force of in-flight, physiological incidents did not identify contaminants as a root cause in any reported cases; however, a gap exists in the ability for real-time monitoring of the pilot air supply. Development of an orthogonal sensor suite for use in flight will enable continuous assessment of pilot air quality and will prove invaluable in the evaluation of OBOGS efficiency and pilot safety. Finally, real-time detection of potential contaminants would allow investigators to determine if those compounds may contribute to future incidents and, if so, what the source is, thus enabling engineers to eliminate or mitigate the problem and ensure protection of the pilots and their full capability to operate the aircraft.

Monitoring the OBOGS product air in-flight presents many technical challenges not faced by ground based air quality analysis [1-5]. As high-performance aircraft are extremely limited in terms of space and weight, any fielded sensor packages must be minimal in terms of their space footprint and weight. The device must function in a high oxygen, low humidity environment which may experience rapid altitude (pressure) changes as dictated by the mission [6]. Additionally, as the developed sensor platform would be used for both determination of atmospheric gas make-up as well as broad screening of potential volatile contaminants, a variety of sensor technologies (i.e., utilizing techniques such as ion mobility spectrometry) may be required for detection of volatile compounds at thresholds below physiological relevance [7-8]. Design considerations will also have to be made for a platform which performs non-obstructive sample collection in the pilot air stream, does not introduce potential leaks in the air supply, and contains all required electronics and algorithms necessary for signal processing, compound identification and quantitation, display, and data logging. The ability to post-process data to identify contaminants not present in the pre-programmed library is desirable as well as is the collection of samples onto media suitable for removal and analysis in a laboratory setting (for purposes of verification and unknown compound identification).

PHASE I: Successful completion of Phase I will require development of a sensor suite with ability to detect the atmospheric components of breathing air, as well as a broad range of volatile organic compounds. A list of specific target compounds and chemical classes will be provided. The Phase I prototype will not require completion of the sample collection, signal processing and display modules.

PHASE II: Phase II will focus on end-to-end implementation of the sampling, sensing, and electronics necessary for real-time, air quality sensing in a form factor compatible with in-flight testing. The developed sensor package will not be required to be self-powered, but should be capable of sustaining operation in flight conditions on-board a high performance aircraft (i.e., high G, variable pressure, high vibration environment). Interface, power, and form factor specifications will be provided.

PHASE III: Follow-on activities to be pursued by the offeror, including government and civilian use, i.e., aerospace industry. Benefits include revolutionary capability for monitoring and early mitigation of cabin air contaminants. Core technology basis for hand-held and fixed site air quality sensing.

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KEYWORDS: air quality, orthogonal sensing, cockpit sampling, electronic nose, ion mobility spectrometer, particle ionization detector, selective gas sensing

AF151-024 TITLE: Advanced Learning Management System (LMS) for State-of-the-Art for Personalized Training

TECHNOLOGY AREAS: Human Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Development of a learning management system that can be used by instructors and researchers to advance the state-of-the-art in personalized training.

DESCRIPTION: The Department of Defense is preparing for substantial cuts over the next decade to military budgets. Despite commanders stating that personnel are the most valuable asset, when budgets decrease, training is often the first thing cut. It is imperative that, as we move to even more complex operational environments, we are leveraging developing technologies to ensure our airmen are developing and maintaining competency.

Currently, Air Force training is based on a one-size-fits-all approach that involves instructor-led classroom-based training and document reading-based certification. The degree to which a particular student develops competency from these approaches is rarely assessed. The state-of the-art in Air Force training research is the development of adaptive, personalized competency-based training technology which emphasizes the development of proficiency instead of simply tracking completion.

To accomplish this goal will require the development of an advanced learning management system that allows for position-specific personalization (at the job duty level), captures individual differences in training efficiency and retention by training type (e.g., classroom-based, computer-based, scenario-based), and provides personalized recommendations using advanced biostatistical analysis techniques adapted from personalized medicine.

The current-state-of-the-art learning managements systems are largely focused on identifying training requirements by position. One issue with this level of personalization is that two people can hold the same position title within an organization, but their day-to-day job may involve supporting very different mission sets with distinct software and tasking. This means that a person might have to accomplish substantial training in areas that are not relevant to their position. The first objective of this topic is to develop a Learning Management System (LMS) that is personalized by mission and position. The system would have the capability to identify the software on a desktop and use this as one input to determine the optimal training pathway that is relevant for the position. This would enable a much finer level of granularity and an initially more narrowly focused training plan, leading acceleration of the acquisition of initial competencies required for their job. As an individual develops expertise, the training plan would increase the breadth. Throughout an individual’s career, the LMS would track the development of knowledge, skills, and experiences.

Current learning management systems being developed will track an individual’s knowledge, skills, and experiences across their career and recommend additional training based on gaps. One gap with existing systems is that they fail to account for individual differences in learning efficacy and retention with different types of training. Future training will be a combination of classroom, computer, and scenario-based training. Research indicates that there are often substantial individual differences in training outcomes (e.g., Allen, Hays & Huffardi, 1986; Gully et al., 2002). Currently, if a competency is not met after a training session is completed, the LMS will recommend the student take the same training again, with minor differences, if any, to the training mode. While additional repetition alone can sometimes compensate for learning challenges in a particular area, changing the mode of training can offer larger training gains. Current systems do not offer this level of tracking or flexibility to provide prescriptive training recommendations taking into account individual learner propensities.

The challenge of providing personalized recommendations to address individual differences has been addressed in other fields, such as personalized medicine. In the area of personalized medicine, the concept is that the collection of metadata regarding an individual's profile, along with treatment outcomes, can not only improve the ability to make future treatment choices for that individual but can also improve the ability of doctors to identify which treatment options will be the most effective for similar patients. Researchers are using advanced statistical techniques to interpret the vast amounts of health data from genetic profiles to side effects experienced in order to provide recommendations. This kind of personalized care has already made significant gains in patient health.

The LMS to be developed here should leverage similar methodologies to identify the optimal training pathways based on the vast amount of data contained in military learning management systems (e.g., deployments, position data, prior training data) and provide training recommendations. It would contain data such as recency, organization, position, where the knowledge, skill, or experience (KSE) was acquired, and the category of KSE. The LMS would allow researchers and instructors to analyze the data to look at training questions such as skill decay for different training types (e.g., by comparing at recency of training versus competency level at refresh). This would eventually allow trainers and researchers to identify optimal training modes that maximize retention and allow for the development of personalized refresher training requirements. This would provide the data the Air Force needs to push past the standard annual training requirement and provide training that maximally supports developing our force.

Finally, the system should track data in a way to allow for a cross-organizational analysis of knowledge, skills, and experiences. The system would aggregate training data and provide a repository which contains knowledge, skills, and experiences for positions across the Air Force. The repository would be flexible (i.e., allowing more fields to be added) and searchable. The database would give instructors the ability to perform cross-organizational analyses of experiences that would allow for the understanding of ways to apply existing training environments to new domains to facilitate the development of expertise in our warfighters. It would also aid the prioritization of funding for the development of new training environments to maximize the cross-domain utility.

The Phase I work should be focused on Command and Control, Computers, Communication and Intelligence, Surveillance and Reconnaissance (C4ISR) domains. The C4ISR domain includes a diverse array of training opportunities and career fields. Optimizing training efficiency for these domains would have a significant impact in maximizing Air Force capabilities for C4ISR.

PHASE I: Define the system requirements. Identify appropriate components to create a system design. Analyze the software necessary to enable the system to work. Propose a design to be built and demonstrated during Phase II. Demonstration of laboratory prototype hardware during Phase I is highly desired, but not required.

PHASE II: Build and demonstrate the training system in a relevant environment. The system must meet requirements as stated in description above. Additionally, design should show significant consideration for human factors, including, but not limited to: flexibility, modularity of design, adaptive to changing environments, tailorablility and inclusion of cognitive science advancements. Level of the system by the end of Phase II is Technology Readiness Level (TRL) 6, and preferably TRL 7.

PHASE III: A personalized training system will need to be able to be leveraged across multiple domains. Phase III development should increase cross-domain interoperability and stability of the system. The goal of the Phase III would be a multi-domain demonstration and integration testing.

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KEYWORDS: learning management, personalized learning, biostatistical analysis, competency-based training, Mission Essential Competencies, LMS, cross-organizational analysis

AF151-025 TITLE: Multi-Channel, High Resolution, High Dynamic Range, Broadband RF Mapping System

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a system to characterize electromagnetic field maps in the near field of RF emitters. The system should be capable of measuring magnitude and phase of electric and magnetic field and shot to shot variation at an array of locations.

DESCRIPTION: The DoD has the need to map electromagnetic fields in the near field of RF emitters in order to predict bioeffects of accidental exposures and improve the performance of antennas. The system should be capable of measuring magnitude and phase of electric and magnetic fields, and characterizing shot to shot variation at an array of locations across the aperture of an emitter ranging in size from a few square centimeters to approximately 3 square meters. The developed technology should be capable of fully characterizing the field at multiple locations (16 to 64), simultaneously. If measurements are to be made with in-field probes, the measuring probes should be made of materials that minimize field perturbation and allow measurements with high spatial resolution. The system should be capable of measuring pulsed and continuous fields from 1/10th the DODI 6055.11 controlled area maximum permissible exposure limit up to air breakdown. The system should measure fields with frequencies of 10 MHz to 300 GHz and pulse widths from continuous (or very long) to a few nanoseconds. The system should be shippable by commercial means (e.g., Fedex or UPS), transportable to field locations, weigh less than 70 lbs, and be operable off batteries or generator power. Multiple pieces of equipment to cover the range of field strengths and frequencies are acceptable.

State of the art RF mapping systems generally use optoelectronic sensors to map electric fields. Due to their limited dynamic range and noise background, collection of numerous pulses with coherent averaging are required to detect pulses of moderate energy. As a result, it is often not possible to characterize shot-to-shot variation in pulsed electric fields. Magnetic field detectors are available, but generally have not been incorporated into field mapping systems. Alternative approaches using antennas do not allow the measurement of field strengths near air breakdown with high fidelity.

The measurements made by this system will be used to populate models of RF interaction with biological materials, perform accurate dosimetry for scientific studies of RF bioeffects, predict biological effects from RF overexposures, and characterize RF emitters for engineering design studies.

PHASE I: Design a system to meet the specifications. Demonstrate through laboratory testing, modeling and simulation, or comparison to existing technologies, that the system design will meet specifications. Identify areas where the specifications cannot be met within the state-of-the-art. Identify promising technology development pathways that will allow improvements beyond the scope of the SBIR effort.

PHASE II: Develop a prototype system that implements the system as designed in Phase I. Collaborate with government personnel to test the prototype at a range of frequencies and pulse widths.

PHASE III: Develop a commercial system that can be used by a variety of industries to make improved field maps for product development/research. Other potential users beyond the sponsoring organization include antenna and RF system developers, biomedical application companies and the semiconductor industry.

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KEYWORDS: RF, field mapping, array, high field

AF151-026 TITLE: Phantom Head for Transcranial Direct Current Stimulation Current Model Validation

TECHNOLOGY AREAS: Human Systems

OBJECTIVE: Develop a phantom head and skull capable of measuring direct currents applied transcranially within the brain and extracortical tissues.

DESCRIPTION: This effort aims to develop a phantom skull capable of measuring and recording electric currents delivered by a non-invasive brain stimulation technique known as transcranial direct current stimulation (tDCS). The phantom will then be used by the government customer to validate existing model predictions of electric current flow inside the human head. This validation will allow modeling to be used to optimize tDCS electrode design, scalp placement, intensity and electrode montage to enhance cognitive performance or efficacy of therapeutic treatments for a variety of neurological ailments.

Transcranial direct current stimulation (tDCS) has been shown to improve cognitive functions in healthy people such as attention, memory and learning (e.g., Reis et al., 2009; Grosbras & Paus, 2003; Ohn et al., 2008; Flöel et al., 2008), and several reports within the Department of Defense have speculated about the possibility of using noninvasive brain stimulation (NIBS) for troop enhancement (Russell, Bulkley, & Grafton 2005; Nelson, 2007). Additionally, NIBS techniques have applications to the treatment of a variety of neurologic conditions such as major depressive disorder, stroke rehabilitation, traumatic brain injury, etc. The tDCS technique modulates the neurons’ resting membrane potential by passing a small electrical current (= 2 mA) between two electrodes placed on the scalp. This passage of current then creates a net increase or decrease in excitability in targeted areas (Paulus, 2004; Priori, 2003). This altered excitability leads to an increase or decrease in local brain activity which can alter human performance/behavior. To be effective, tDCS must target the task-specific brain areas or networks. Because the current pass through a variety of tissues to reach the cortex such as skin, skull, cerebral spinal fluid, and fat the electrical resulting current flow can be non-intuitive and often is dependent on regional tissue conductivity and anatomical features/structure. Effectively, it is insufficient to select scalp locations directly over the brain region of interest due to the fact the current may flow in an unexpected manner. In an effort to optimize electrode placement for targeting of specific brain areas and optimizing human performance or therapeutic treatment effects, tDCS current flow models have been developed (e.g., Datta, et al., 2009; McKinley, et al., 2013). Unfortunately, there is currently no methodology of device to empirically validate these models due to the fact it would require measurement within the human brain. Additionally, holes or cracks in the skull change the passage of current into the brain due to the fact that the skull has low conductivity. By validating these models with a phantom skull, they could be used to identify optimal scalp locations, intensity, design, and montage for electrode placement for a variety of human performance enhancement and therapeutic treatment applications.

It is anticipated the measured current range in the brain tissue is on the order of a few nano-amps up to 100 milli-amps, therefore, the phantom much be able to have suitable gain to measure in this range. In addition, the phantom much be able to measure other electrical properties including resistance/impedance and voltage. It is desired that the phantom have a measurement resolution of at least 1 cm2. Finally, the measurement system within the phantom must also be capable of taking measurement from electrodes in-vitro (e.g. animal subject living tissue) environment and implanted electrodes placed in a human post-mortem skull.

PHASE I: Select a promising phantom skull (i.e., in tact with no unnatural cracks, holes or cuts) and determine realistic materials/tissues to mimic brain, skin, cerebral spinal fluid and other extracranial tissues. Perform preliminary investigations to determine optimal sensors and placements for measuring electrical properties and direct currents within the phantom tissues.

PHASE II: Construct, demonstrate, and optimize the phantom head. Conduct tests of the phantom using traditional and newly developed tDCS electrodes. The newly developed tDCS electrodes will be provided on loan by the government to conduct the testing.

PHASE III: Use the phantom to validate models of transcranial direct current stimulation current flow within the brain published in the open literature. This will allow for optimization of the electrode placement to enhance cognitive skills such as attention for military tasks such as image analysis.

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KEYWORDS: transcranial direct current stimulation, non-invasive brain stimulation, NIBS, human augmentation, modeling, phantom

AF151-028 TITLE: <u>Semantic Technology for Logistics Systems Interoperability and Modernization</u>

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop/demonstrate foundational elements of a semantic technology solution for Air Force and commercial logistics systems interoperability and modernization to achieve Agile Combat Support, the rapid deployment & sustainment for military operations.

DESCRIPTION: Air Force logistics information technology modernization efforts require an understanding of current business and process rules, interfaces, data, data relationships and data dependencies within the application environment. Interoperability of modern and legacy systems requires foundational understanding of the data syntax and semantics within and exchanged by legacy systems. This is particularly critical if an existing system is going to be modified or subsumed, either partially or wholly by modernization. Semantic technologies have demonstrated successes in achieving system interoperability and modernization in the intelligence, medical, biological and pharmaceutical domains.

The logistics community needs a semi-automated approach to quickly analyze the syntax and semantics of the current data environment from structured and unstructured information and evolve it for system interoperability and modernization. The solution should drive a common view of data formally capturing the logistic domain knowledge using an ontology and a shared vocabulary of concepts, types, properties, concepts relationships and rules. The solution must produce machine and human understandable information for federation between information systems to enable machine computable logic, inferencing and knowledge discovery.

Proposals should address the technical solutions that will be explored for delivering the necessary capabilities described above as well as the transformations to enable interoperability. Semantic technology achieves most of the goals of the DoD net-centric data strategy where data must be visible, accessible, usable, discoverable, trustable and interoperable. The net-centric policy relies heavily on metadata for understanding, discovery, provenance and security.

This product must address the following objectives:
• The proposed solution should use World Wide Web Consortium (W3C) semantic recommendations (e.g., Web Ontology Language and Resource Description Framework), as well as semantic technology best practices including rules of linked data and ontology reuse.
• Foundational logistic ontologies should be the basis to evolve systems interoperability and modernization and support logistic strategic, operational and tactical points of view.
• Provide the ability to visualize and categorize the information created by the systems so that users can better understand the information relationships and context.
• Use of open-source software use is encouraged where possible.
Be able to operate with diverse application programming languages, databases/data storage, operating systems, infrastructures, hardware, and supporting application.

PHASE I: Develop a prototype for semantically linked logistic data and foundational vocabularies/ontologies. Explore approaches to semantic logistics interoperability/modernization and advanced queries with AF chosen systems. Explore approaches to ensure restricted access to sensitive data and computational techniques to process sensitive data at unclassified sites, e.g., commercial and university.

PHASE II: Further mature the foundational midlevel logistics ontology for initial prototype use that supports DoD crowd sourcing of the ontology. Explore more sophisticated lower-level ontologies for the logistics domain.

PHASE III: Extend and transition the prototype to operational use.

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2. World Wide Web Consortium Semantic Website: http://www.w3.org/standards/semanticweb/.

3. DoD and the Semantic Enterprise “Heading, Altitude, and Airspeed” video: https://www.youtube.com/watch?v=pkhj2sTPlbk.

KEYWORDS: agile combat support, logistics, semantic technology, ontology, legacy systems, system modernization

AF151-029 TITLE: Infrastructure Agnostic Solutions for Anti-Reconnaissance and Cyber Deception

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: This topic seeks to provide new and novel approaches to delaying, disrupting and deceiving adversaries engaged in active network reconnaissance.

DESCRIPTION: The collective stages used to infiltrate a system can be applied to perform a broad range of attacks. However, the most successful assailants rely heavily on the reconnaissance stages, which are primarily divided as passive or active approaches [1]. Passive reconnaissance is a mere collection of information using search engines or various other methods in obtaining publicly available information. This form of information gathering requires entities to practice discretionary posting of information and is often a disregarded tactic used by sophisticated criminals today. The active reconnaissance approach generally results in the act of probing and scanning hosts or servers to determine IP addresses, database information, operating systems used, passwords, usernames, etc. While defensive tactics such as monitoring traffic flow with intrusion detection systems (IDS) or stateful firewalls can help detect active reconnaissance practices, attackers are still able to administer stealthier techniques, such as sending smaller amounts of packets to avoid detection. Since reconnaissance is generally the preceding stage in an attempt to compromise a system, attackers can successfully perform a multitude of attacks on target systems using the gathered information. As such, increasing the effort required on the part of the adversary to obtain actionable intelligence, or providing inaccurate information altogether can enhance the overall security posture of a system or network [2].

There is a need for secure, infrastructure agnostic, solutions designed for cyber agility and anti-reconnaissance. Such solutions must effectively prevent traffic analysis, and must implement evasive and deceptive techniques such as misreporting source and destination IP and/or MAC addresses, and intermittently changing those addresses. The technology must be capable of preventing an adversary from accurately determining the direction or volume of information moving within the network, or the size or topology of the network itself, and must be capable of taking measures to prevent, detect, and cease communication with non-compliant or rogue clients within the environment.

Consideration will be given to solutions that 1) have little to no impact to network performance or the availability of services, 2) those that do not require customized, or otherwise "non-commodity" hardware, 3) those that provide for flexible infrastructure or enclaves that can be set up, re-segmented, and/or taken down quickly, and 4) those that are capable of supporting a PKI or other robust cryptosystem. The performer should not assume that solely providing a large address space, in which it is difficult for the attacker to predict the next address, provides a sufficient level of assurance.

PHASE I: Research, and design the overall architecture to address the requirements. Define the types of data that can be collected for metrics and concepts for adaptive remediation. Ideally at the end of Phase I performers will be able to provide a proof-of-concept demonstration.

PHASE II: Develop an enclave with this capability and test against representative enterprise networks and environments.

PHASE III: Work with the DoD to demonstrate that the prototype developed during Phase II can also be applied to DoD systems and software. Further demonstrate and deploy the capability within diverse environments.

REFERENCES:
1. U.S. Naval Academy. Phases of a Cyber-Attack / Cyber-Recon. US Naval Academy. [Online] http://www.usna.edu/CS/si110arch/si110AY13F/lec/l32/lec.html.

2. Thwarting cyber-attack reconnaissance with inconsistency and deception. Rowe, N and Goh, HC, Information Assurance and Security Workshop, 2007. IEEE SMC, 2007.

KEYWORDS: agility, deception, reconnaissance, avoid attack, cyber situation awareness, moving target defense

AF151-030 TITLE: Cyber Hardening and Agility Technologies for Tactical IP Networks (CHATTIN)

TECHNOLOGY AREAS: Information Systems

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OBJECTIVE: Demonstrate computer network defense that will enable tactical IP networks to eliminate vulnerabilities that may be exploited to launch an attack, and implementing cyber agility techniques to thwart attack planning/execution.

DESCRIPTION: IP-based aerial layer networks must be protected against cyber attacks for assured mission operations. Traditional reactive computer network defense techniques have to constantly play “catch-up” to an ever increasing array of cyber attacks being designed by our adversaries. Currently, the extent and fixed nature of the attack surface presented by tactical IP networks provides our adversaries with the opportunity to carefully plan their attacks over time and to launch them at a time and place of their choice.

The Air Force is seeking new computer network defense technologies which can reverse this asymmetry that favors our adversaries. Of specific interest are cyber hardening and cyber agility techniques for avoiding cyber attacks which provide a strategic cyber advantage by reducing or eliminating the need to fight, increasing the cost, time, and difficulty to launch an attack, and reducing the probability of a successful attack.

Cyber hardening techniques reduce the extent of the exposed attack surface by eliminating vulnerabilities in networking protocols and services that may be exploited by adversaries to launch attacks. For instance, a network routing protocol that lacks authentication is vulnerable to spoofing attacks that can subvert the operation of the network. For this case, cyber hardening would involve incorporating the necessary protocol message authentication techniques. Approaches for cyber hardening aerial IP networks that preserve existing investments in network infrastructure, e.g., tactical IP radios, are desirable to ones that require replacement of network equipment.

Cyber agility techniques avoid network attacks by performing evasive defensive maneuvers that present a “moving target” to the adversary making it extremely difficult for the adversary to obtain a fix on the target for launching a successful attack. Such real time network agility may be accomplished using a variety of synthetic redundancy and polymorphic techniques within the network architecture. For instance, IP address and port hopping between communicating end points on a network may be used to obviate attempts by an adversary to track and target critical systems. Similarly, cyber agility techniques can be used to dynamically reconfigure the posture of a system upon the onset of an attack to enable the system to fight through the attack and provide continued uninterrupted operations. The key challenge here is to develop network agility techniques that are transparent to authorized users of the network and that introduce minimal steady state overhead.

PHASE I: For Technology Readiness Level (TRL) 4, develop multi-threaded means to reduce attack surfaces in the tactical networking environment. Consider manned and unmanned aerial and mobile surface environments, plus the access to the GIG at forward-deployed locations.

PHASE II: For TRL 5, provide demonstration of dynamic network configuration while under attack in a simulated/emulated laboratory environment.

PHASE III: For TRL 5/6, provide and execute a transition plan to FAA airborne IP network hardening and protection. Mature the prototype at TRL 6/7 and demonstrate its capability under representative airborne network operational scenarios.

REFERENCES:
1. Kamaal Jabbour and Paul Ratazzi, “Does the United States Need a New Model For Cyber Deterrence?”, in Deterrence: Rising Powers, Rogue Regimes, and Terrorism in the Twenty-First Century, edited by Adam Lowther, Palgrave Macmillan, 2012.

2. The Connectivity Challenge: Protecting Critical Assets in a Networked World, a Framework for Aviation Cybersecurity, AIAA, Aug 2013.

KEYWORDS: cyber, hardening, aviation network, critical assets, attack surface, robust RF assets

AF151-031 TITLE: Malicious Behavior Detection for High Risk Data Types (DetChambr)

TECHNOLOGY AREAS: Information Systems

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OBJECTIVE: Create a technical capability/hardware for the Air Force that is able to detect malicious executable content based upon detection of adversarial malicious behaviors (as compared to malicious code signatures).

DESCRIPTION: Commercial virus scanners rely upon signatures of code segments in order to identify malicious code. These solutions are unable to address custom crafted malicious payloads until they are exposed to the broader community, nor do they adequately address the challenges presented by tools that can obfuscate malicious binaries by hiding/changing these code signatures. Detecting malicious behaviors in a representative environment (e.g., attempting to create alternate data channels beyond those normally used by the application).

The intent of this capability is to both support detection of polymorphic transformations of existing malicious code and either signature or anomaly-based detection of potential zero day attacks. Solution should also include an approach for self-protection against malware escape attempts (e.g., hypervisor introspection).

PHASE I: Build a malicious/anomalous behavior-based data type inspection tool. Show a proof of concept that can detect and report any anomalous unexpected behaviors initiated by opening/executing a fiel in a representative computing environment.

PHASE II: Further harden and instrument the infrastructure developed in Phase I. Develop approaches to rapidly support baseline "normal" data type behaviors and integrate them into the detonation chamber. Test the prototype against new, complex data types (e.g., Analyst Notebook), including custom attacks that are not currently covered by a commercial virus scan.

PHASE III: Commercialize the product and provide it for sale or via open source license to DoD, IC and commercial purchasers. Additional business opportunities in training, subject matter expertise etc. also exist.

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1. http://www.schneier.com/blog/archives/2012/06/the_failure_of_3.html.

2. http://en.wikipedia.org/wiki/Virtualization.

3. https://tails.boum.org The Amnesic Incognito Live System (TAILS), using a two-layer virtualization system for confidentiality rather than integrity.

4. http://sourceforge.net/p/whonix/wiki/Home/ Another confidentiality-based project using two-layered virtualization.

KEYWORDS: virtualization, detonation chamber, malware detection, blue pill/red pill malware, hypervisor introspection

AF151-032 TITLE: MIMO functionality for Legacy Radios

TECHNOLOGY AREAS: Electronics

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OBJECTIVE: Achieve multi-path and multiple-input/output (MIMO) performance from legacy software-defined radios without modification of the radio, itself, or the waveform(s).

DESCRIPTION: Multi-Antenna, MIMO, techniques have been proven to significantly improve the throughput, reliability and range of wireless communication systems. Subject to environmental conditions, the work in the literature touts as much as 20 dB improvement in the link margin, up to 10x reduction in the TX power for the same throughput, up to 30 dB of interference mitigation, and several factors improvement in the achievable throughput.

To achieve these gains current MIMO systems require that the antenna processor be embedded deep inside the Physical Layer processor. They also require changes to packet structure to allow MIMO channel estimation. Unfortunately due to the large installed based of legacy radios and the time frame needed for the introduction of new waveforms and hardware into airborne platforms, such an embedded approach will take decades to deliver any substantial benefits to airborne communication systems.

It is desired to bring most, if not all, the benefits of an embedded MIMO wireless system to as many airborne links as possible. The MIMO benefits should be delivered in a separate bolt-on appliqué module and should in no way modify the legacy over the air waveform (a must for backward compatibility with non-MIMO enabled legacy radios).

The proposed appliqué solution should require little if any modifications to the legacy radio. It should act as a standalone fully self-contained solution that delivers MIMO gains this may include one or more of the following advantages, such as TX and RX generalized beam forming, Space Time coding, spatial multiplexing and interference mitigation.

PHASE I: Provide a simulation demonstrating the benefits of a separate MIMO applique capability without modifying the radio or the waveform.

PHASE II: Using commercial off-the-shelf (COTS) transceivers, demonstrate MIMO capability in a laboratory. Deliver software development kit. Demonstrate radios in a suitable multipath environment.

PHASE III: Select a number of specific tactical transceivers for follow-on work. Demonstrate using the software development kit. High potential for commercial use with ability to extend capability of MIMO to commercial, Homeland Defense, and first responder systems.

REFERENCES:
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2. Gardellin, V. et al., The MIMONet Software Defined Radio Testbed, Institute for Informatics and Telematics.

3. Mizutani, K. et al., Dev MIMO-SDR and Application to RT Channel Measurements, SDR Radio Technology.

KEYWORDS: MIMO, multiple input, multiple output, SDR, software defined radio, multipath

AF151-033 TITLE: Virtual Trusted Platform Module (vTPM)

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: This SBIR topic seeks to investigate techniques for providing vTPM support in the Quick Emulator (QEMU), such that software executing in virtual/emulated environment can leverage TPM technologies.

DESCRIPTION: Recently, virtualization has been used on client end-point devices to increase security through isolation, and increase availability through multiple access [1]. Even mobile devices have started leveraging virtualization [2].

In addition to the increased use of virtualization, almost all business class workstations and laptops comes standard with an on-board TPM. Some tablets already have support for TPMs, and the Trusted Computing Group has created a mobile version of the TPM specification [3, 4]. TPMs today are used in numerous technologies including measuring software like Microsoft's BitLocker, securely storing user and Virtual Private Network (VPN) credentials, as well as providing static and dynamic roots of trust such as Intel's Trusted Execution Technology [5, 6].

The above technologies, however, do not function in virtualized environments. It is possible for the virtualization technology itself to take advantage of the TPM (e.g., Citrix XenClient), but there is little to no support for virtualized guest operating systems to leverage the same TPM technologies [1]. The vTPMs are not, however, a new concept. Both IBM and the NSA have created prototype implementations of a vTPM. These prototypes however have not been included in QEMU, which is responsible for the virtual hardware found in most virtualization products today. Since QEMU is so widely used, providing QEMU with vTPM support would enable the use of TPM technologies in a large number of virtualized environments today, as well as bring new forms of security to mobile and workstation environments.

The goal of this SBIR topic is to investigate and develop a vTPM that leverages QEMU to provide guest OSs with a virtual hardware interface capable of supporting existing TPM based technologies. Specifically this SIBR will:
• Provide virtualized guests with a vTPM hardware interface.
• Provide QEMU with vTPM support, such that existing virtualization technologies can impart guest OSs with TPM support.
• Provide a common vTPM API for QEMU capable of supporting existing vTPM technologies

PHASE I: Develop a design for a vTPM hardware interface for QEMU. Develop a design for a common vTPM API for QEMU to communicate with existing vTPM technologies. Prototype the vTPM hardware interface, and demonstrate the common API with a comprehensive test harness.

PHASE II: Develop a complete vTPM solution for QEMU that utilizes the design and prototype developed under Phase I. Integrate the modified QEMU into an existing virtualization technology as well as integrate an existing vTPM technology with the QEMU hardware interface. Test the vTPM solution with the test harness developed in Phase I, as well as existing technologies that leverage a hardware TPM such as Microsoft's BitLocker.

PHASE III: Military: Integrate vTPM into existing DoD/IC networks. Commercial: Integrate vTPM utilized by organizations with sensitive information that are subject to outside attacks, such as financial institutions, defense contractors, and security agencies.

REFERENCES:
1. Citrix XenClient, http://www.citrix.com/products/xenclient/overview.html.

2. Samsung's ARM support for Xen, http://www.xenproject.org/developers/teams/arm-hypervisor.html.

3. TPM Mobile, https://www.trustedcomputinggroup.org/resources/tpm_mobile_with_trusted_execution_environment_for_comprehensive_mobile_device_security.

4. Microsoft's BitLocker, http://windows.microsoft.com/en-us/windows7/products/features/bitlocker.

5. Intel's Trusted Execution Technology (TXT), http://software.intel.com/en-us/articles/intel-trusted-execution-technology.

6. IBM Virtual TPM, http://researcher.watson.ibm.com/researcher/view_project.php?id=2850.

7. NSA Virtual TPM, http://xenbits.xen.org/docs/4.3-testing/misc/vtpm.txt.

KEYWORDS: virtualization, TPM, vTPM, attack detection, attack prevention, CND, CNA, CNO, BitLocker

AF151-034 TITLE: Target Based Data Compression Settings Broker

TECHNOLOGY AREAS: Information Systems

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OBJECTIVE: Develop an application to weigh the environmental and geospatial impacts on image formation and recommend the optimal target based compression algorithm settings based on image quality required to address essential elements of information (EEI).

DESCRIPTION: With the emergence of powerful and tunable compression algorithms [1], there is a need for reliable and consistent settings for data quantity (compression) and data quality (exploitation) by mission planners to insure operational imperatives are satisfied. Compression methods should be developed in consideration of other factors such as transmission bandwidth [2], exploitation needs [3], and requirements. Compression can be achieved pre-processing or post-processing of sensor collection using various methods such as in hardware and software [4]. Various compression choices effect target classification, multiple-target tracking, and activity based intelligence.

Sensor phenomenologies (Synthetic Aperture Radar, Hyperspectral, LIght Detection and Ranging, Electro-optical/Infrared) impose specific, sometimes unique, considerations on sensor collection attributes and must be tailored to specific targets and mission parameters in order to optimize image quality such as the National Imagery Interpretability Rating Scale (NIIRS) needed for EEI satisfaction [5]. Settings to control compression in order to optimize bandwidth transmission and maximize data collection must be weighed against the data fidelity essential for exploitation and analysis. Additionally, considerations such as target location/orientation with respect to the geospatial positioning of the sensor and environmental conditions compound the mission planning and data/scene collection equations. Each of these considerations taken as a holistic set of variables has the potential of influencing the data fidelity required to answer specific operational imperatives. Operational needs can be achieved from single or multiple source sensor fusion techniques that are dependent on image quality. Therefore the ability to precisely balance compression to accommodate mission expectations for bandwidth optimization with the data fidelity required for exploitation during the mission planning stage is critical and could be mitigated by a broker to optimize compression settings. A successful offeror can work with the technical point of contact (TPOC) to define relevant data, scenarios, and operational scenarios of interest to the DoD to evaluate target-based data compression settings tradeoffs.

Multi-phase development should incorporate an adaptive trust metric with feedback to monitor and reinforce appropriateness of compression algorithm settings to satisfy the mission requirements for data throughput (bandwidth optimization) and data quality. Developments should include and assessment of metrics such as quality of service and information quality measures of performance and measures of effectiveness (e.g., reliability, trust level, exploitation accuracy, timelines) for selecting the most appropriate compression setting for operational success (EEI satisfaction). Metrics for EEI satisfaction based on the Data Fusion Information Group model should be developed for operational readiness. The metrics should account for the variables imposed in the collection problem set and assist mission planners to optimize compression settings (e.g., Level 0 fusion) based on operational results and feedback (e.g., Level 5 fusion).

PHASE I: Phase I is intended to identify sensor collection variables that affect target EEI satisfaction. Prototype examples using available data and compression techniques with the EEI variables should afford feedback from exploitation verification and data collection validation. Methods of exploitation quality should be demonstrated in a multi-modal fusion system performance results.

PHASE II: The intent of Phase II is to implement and select design parameters experienced in Phase I. EEI satisfaction likelihood is understood based on the sensitivity to the sensor characteristics, environment, and needs for target detection to identification impacting mission needs. Compression, exploitation, and fusion results should be demonstrated in a system's tool that integrates standards, mission requirements, and suggestion optimal performance parameters.

PHASE III: Phase III is intended to utilize the developed tool in Phase II as a settings broker component within an imagery intelligence pipeline. Methods developed can support EEI satisfaction for on-the-fly parameter adjustments at the sensor or at the image receiving and exploitation center.

REFERENCES:
1. G. Motta, F. Rizzo, J. A. Storer, Hyperspectral data Compression, Springer, 2006.

2. J. Patrick, R. Brant, and E. Blasch, "Hyperspectral Imagery Throughput and Fusion Evaluation over Compression and Interpolation," Int. Conf. on Info Fusion, 2008.

3. B. Kahler and E. Blasch, "Predicted Radar/Optical Feature Fusion Gains for Target Identification," Proc. IEEE Nat. Aerospace Electronics Conf. (NAECON), 2010.

4. V. M. Patel, G. R. Easley, D. M. Healy Jr, R. Chellappa, "Compressed Synthetic Aperture Radar," IEEE Journal of Selected Topics in Signal Processing, Vol. 4, 2, 244-254, April 2010.

5. MISB ST 0901.2, "Video-National Imagery Interpretability Rating Scale," 27 Feb. 2014.

KEYWORDS: compression, adaptive, hyperspectral, Wide area motion imagery, synthetic ap radar, trust metrIc, EEI, DFIG, level 5 fusion

AF151-035 TITLE: Miniature Link-16 Communications Device

TECHNOLOGY AREAS: Information Systems

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OBJECTIVE: Develop and demonstrate a prototype miniature Link-16 communications device.

DESCRIPTION: Tactical Data Links (TDL) provide essential communication channels between forces to support interoperability. The most common TDL for U.S., NATO and Coalition forces is Link-16. Link-16 provides near real time exchange of tactical data among military units and is the global standard for modern command and control (C2) architectures.

Unfortunately, size, weight, and power (SWaP) constraints of current Link-16 components prevent the dismounted operator from directly utilizing the Link-16 network. The objective of this SBIR is to develop a miniature device design that minimizes SWaP to enable the dismounted operators to fully implement the Link 16 capability to enhance situational awareness (SA) and C2. Market research suggests that a handheld Link-16 device, comparable to the Harris Corporation's AN/PRC-152 radio, will be available by FY 2016. This effort will focus on continued reduction of SWaP of miniature Link-16 devices.

PHASE I: Design a miniature Link-16 communications device and perform analyses to establish operational (voice/data/networking) capabilities with reduced SWaP requirements. Develop a System Implementation/Test plan for evaluating device operating performance and which adresses all NSA, FCC, and other applicable certifications required to operate in both non-secure (Threshold) and secure (Objective) modes.

PHASE II: Produce a "breadboard" Link-16 communications device for evaluating and demonstrating operational performance and which addresses: Link-16 waveform (voice/data/networking) functionality, planning for Information Assurance (IA) and security certifications, receive sensitivity, transmit power, RFI and EMI, SWaP, thermal and prime-power management, and configuration/control/data interfaces. Develop a design for a prototype Link-16 device, with a miniature form-factor, suitable for field testing.

PHASE III: Assemble a prototype miniature Link-16 communications device and conduct field tests to verify (voice/data/networking) operational performance, in a secure manner, and demonstrate functional capabilities with reduced SWaP.

REFERENCES:
1. DoD 4650.1-R1, Link 16 Electromagnetic Compatibility (EMC) Feature Certification Process and Requirements, April 26, 2005, http://www.dtic.mil/whs/directives/corres/pdf/465001r1p.pdf.

2. TADIL J, Introduction to Tactical Digital Information Link J and Quick Reference Guide, June 2000, http://www.globalsecurity.org/military/library/policy/army/fm/6-24-8/tadilj.pdf.

KEYWORDS: tactical data link, TDL, communication, handheld, Link 16, Special Operations Forces, SOF, dismounted, command and control, C2

AF151-036 TITLE: Adaptive Agentless Host Security

TECHNOLOGY AREAS: Information Systems

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OBJECTIVE: This topic seeks to provide new and novel approaches to protect, fight-through, and recover from compromises at enterprise scale networks without (or very limited) agents on endpoint systems.

DESCRIPTION: Enterprise networks are under constant attack and the techniques being used the adversary routinely evade existing host and network based security applications. Current defensive technologies commonly utilize a persistent defensive agent(s) on the each network system or workstation. The continued proliferation of attacks suggests that the current agent-based approaches to enterprise resiliency have limited effectiveness in protecting systems from compromises. The deployed agents add a significant overhead, drastically reduce performance [1], increase vulnerable attack surface, and act as a single point of failure that is the first target in any attack. If the agent is incapacitated, the system is in a state with limited defensive, monitoring, and remediation options available. In the end, current solutions are reducing operator efficiency while not providing resilient and adaptive host-based security.

To provide a resilient enterprise host and network defense capability, new techniques must be developed that move beyond the current approaches failing the network defenders. Existing techniques that have limited effectiveness for identifying and countering new attacks include system baseline, artifact signatures, and file type guards [2]. This topic seeks to take a proactive and adaptive approach to protecting, and defending the enterprise infrastructure by developing methods that support network resiliency, fight-through, and survivability [3]. The proposed techniques for protecting, defending, and remediating compromised hosts must demonstrate evidence to achieve enterprise scale (i.e., solutions should be able to scale beyond 10,000 hosts). Preferably, the solution should minimally invasive and ideally not include the requirement for significant new hardware on the network such as a centralized server. It is expected that proposed solutions will be agentless and not significantly rely on baselines or signatures. The live capture of information from systems will have minimal effect on system performance and will seek to first utilize common interfaces for integrating an endpoint. It is assumed that collected data will support the development of information assurance metrics that can be utilized for remediating and adapting defenses to recover to a state of reduced vulnerability. The proposed system must use open or existing protocols, file formats, and/or interfaces to provide extensible design, integration opportunity, and technology transfer. The system shall be able to adapt to new attack methods without immediate direction from a centralized server.

PHASE I: Research, and design the overall architecture to address the requirements. Define the types of data that can be collected for metrics and concepts for adaptive remediation. Ideally at the end of Phase I performers will be able to provide a proof-of-concept demonstration.

PHASE II: Develop the adaptive agentless system and test against representative enterprise networks and environments.

PHASE III: Work with the DoD to demonstrate that the prototype developed during Phase II can also be applied to DoD systems and software. Further demonstrate and deploy the capability within diverse environments.

REFERENCES:
1. IT Web. Cloud Needs Agentless Security., [Online] May 17, 2013. http://www.itweb.co.za/?id=64168:Cloud-needs-agentless-security.

2. MacDonald, Neil. This Just In: Signature-based Protection Ineffective Against Targeted Attacks. Gartner. [Online] January 31, 2013. http://blogs.gartner.com/neil_macdonald/2013/01/31/this-just-in-signature-based-protection-ineffective-against-targeted-attacks/.

3. Cyber Resilience for Mission Assurance. Goldman, Harriet, McQuaid, Rosalie and Picciotto, Jeffrey. s.l. : Technologies for Homeland Security (HST), 2011 IEEE Internation Conference, 2011.

KEYWORDS: adaptive, agents, networks, resiliency, security, proactive defense

AF151-037 TITLE: Special Operations Forces Multi-function Radio

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop and Integrate voice, video & data into a lightweight dismounted system.

DESCRIPTION: Special Operations Forces operators currently carry separate radios for two-way voice communication and video data (to include metadata and command and control or C2). By merging these systems, a weight savings for the load carried by the operator can be achieved without reducing capability; reducing the weight of equipment carried by the warfighter is Air Force Special Operations Command"s number one priority for battlefield airmen. This multi-channel radio shall be able to transmit and receive multiple inputs/signals simultaneously in a meshed IP network. The radio shall require commercial grade encryption (AES) and NSA Type-1 encryption. The new system shall be compatible with existing equipment and capabilities to include: currently fielded radios and applicable voice/video waveforms, cryptographic key loaders, and batteries. The radio shall be ruggedized, using durable materials similar to other currently fielded dismounted systems. The radio should be able to form a mesh network of up to 100 nodes that is self-healing with less than 5 second connect and disconnect times. At 100 nodes the network should see minimal network degradation on throughput. The radio should minimally support 5Mbps data links per channel. This radio system must be easily configurable on the fly in the field by a typical operator with minimal training.

PHASE I: Define the proposed concept and develop key component technological milestones of a multi-channel handheld radio. Additional Phase I deliverables shall include a feasibility study and analysis of predicted performance.

PHASE II: Construct a test unit design, and test plan based on Phase I work. Analyze how the unit will operate in real-world scenarios to include interoperability with other communication devices

PHASE III: Build and test a prototype system. Field testing and validation of interoperability shall be conducted in accordance with previously documented test plans. Minimizing size, weight, and power of handheld radios directly benefits the operator.

REFERENCES:
1. Remotely Operated Video Enhanced Receiver Capabilities Brief, Dec 6, 2011. http://www.slideshare.net/robbinlaird/the-rover-system.

2. AN/PRC-152a Features and Data Sheet, http://rf.harris.com/media/AN-PRC-152A_DataSheet_web_tcm26-18518.pdf.

3. AN/PRC-117G Features and Data Sheet, http://rf.harris.com/media/AN-PRC-117G_WEB_tcm26-9017.pdf.

4. RT-1922C MicroLight Radio Overview http://www.raytheon.com/capabilities/products/microlight/.

KEYWORDS: lightweight, Special Operations Forces, multi-channel radio, transmit/receive, AES, NSA Type-1 Encryption, waveforms, ruggedized

AF151-038 TITLE: Host-Based Solutions for Anti-Reconnaissance and Cyber Deception

TECHNOLOGY AREAS: Information Systems

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OBJECTIVE: This topic seeks to provide new and novel approaches to reduce the adversary's ability to gain an accurate and comprehensive picture of a target environment.

DESCRIPTION: An adversary's building blocks towards successful exploitation are provided through targeted reconnaissance. The underlying goal of reconnaissance is focused on identifying a target host, available services, running applications, or operating system. The path to successful exploitation is paved by allowing the adversary to gain a comprehensive picture of the target environment. The objective of this solicitation is to reduce the adversary's ability to gain an accurate and comprehensive picture of the target environment, such that not only is the adversary misled and deceived [1], but legitimate users are never impacted by the system.

There is a need for solutions capable of, at the host-level, increasing the complexity of the target surface to the attacker and limit the exposure of vulnerabilities. Attackers are capable of observing crucial components and configurations of static target operational environments and the information that is available through public fingerprinting technologies. Much of this information is communicated through standard Internet browsing technologies available to users; to an attacker this is crucial information about a system that can lead to successful exploitation. The proposed solution must falsify externally reported settings and provide a method to randomize the applications utilized. By exposing attackers to a dynamic environment, their ability to perform reconnaissance on a target system will be greatly reduced, while the cost of weaponization and delivery of an exploit will increase, thereby significantly decreasing the likelihood of exploitation [2].

Consideration will be given to solutions that 1) have little to no impact to system performance or the availability of services, 2) those that allow for the rapid staging of workstations, and 3) those that are capable of introducing randomness while still making certain to utilize functionally-equivalent processes and applications.

PHASE I: Research and design the overall architecture to address the requirements. Define the types of data that can be collected for metrics and concepts for adaptive remediation. Ideally at the end of phase I performers will be able to provide a proof-of-concept demonstration.

PHASE II: Develop an enclave with this capability and test against representative enterprise networks and environments.

PHASE III: Work with the DoD to demonstrate that the prototype developed during Phase II can also be applied to DoD systems and software. Further demonstrate and deploy the capability within diverse environments.

REFERENCES:
1. Thwarting cyber-attack reconnaissance with inconsistency and deception. Rowe, N and Goh, HC, Information Assurance and Security Workshop, 2007. IEEE SMC, 2007.

2. Chabrow, E. Intelligent Defense Against Intruders. Government Information Security. [Online] May 23, 2012. http://www.govinfosecurity.com/interviews/intelligent-defense-against-intruders-i-1565.

KEYWORDS: deception, network, reconnaissance, avoid attack, cyber situation awareness, moving target defense

AF151-039 TITLE: Mediated Mobile Access (MMA)

TECHNOLOGY AREAS: Information Systems

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sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: This SBIR topic seeks to investigate techniques for controlling offline and online access to mobile devices, such that data at rest and data in transit is confidential and cannot be accessed without user and device authentication.

DESCRIPTION: Mobile devices facilitate access to controlled resources from potentially unsecured environments. However, this means an increased risk of offline and online attacks, untrusted users, and lost or stolen devices, etc. Virtualization has been used in desktop environments to facilitate access to multiple domains while promoting security via isolation [1]. Recently, there has been increasing interest in supporting virtualization in the mobile space [2], which could allow for significant improvements in protecting data-at-rest, data-in-use, and data-in-transit on mobile devices.

Mobile devices bring a number of challenges including cellular radio devices, wireless control, point of network attachment, voice-over-IP (VoIP), encryption (IPSEC/MOBIKE [3], cellular, VoIP), latency, and throughput. Virtualization can provide a layer of data-in-transit protection transparent to the guest operating system (OS), but a MMA solution will need to address these mobile-specific device challenges.

In addition, mobile devices need to securely store data-at-rest, while maintaining confidentiality in the event the device is lost or stolen. Virtualization can support a layer of storage encryption transparent to the guest OS, ensuring that any data-at-rest will remain inaccessible to an untrusted user.

A critical component that enables these technologies in the mobile space is remote attestation. Remote attestation and measurements of the device could provide a mechanism for authentication and authorization to unlock devices as they are powered on and routinely while in use, providing strong guarantees of the confidentiality of data-at-rest, data-in-transit and data-in-use.

The goal of this SBIR topic is to investigate and develop a virtualization solution capable of providing an Android virtual machine with a virtual hardware interface capable of supporting data-at-rest, data-in-use, and data-in-transit protections. Specifically this SBIR will:

- Provide a virtualization solution designed for mobile devices such as tablets and phones capable of supporting Android guests.
- Provide data-in-transit protection suitable for mobile use, transparent to the guest
- Provide data-at-rest protection suitable for mobile use, transparent to the guest
- Provide data-in-use protection with remote attestation, transparent to the guest

PHASE I: Develop a design for a MMA solution for an Android guest on a tablet with hardware virtualization extensions. Prototype the MMA framework providing protections for data-in-transit and data-at-rest. Test and benchmark the virtualization solution.

PHASE II: Develop a complete MMA virtualization solution that provides full data-at-rest, data-in-transit, and data-in-use protections, with remote attestation functionality for specific tablets and cell phones.

PHASE III: Military: Deploy the technology on actual DoD/IC networks to ensure usability. Commercial: Integrate solution with existing vendor products to provide secure mobile device access within untrusted environments. Utilized by financial institutions, defense contractors, and security agencies.

REFERENCES:
1. Citrix XenClient, http://www.citrix.com/products/xenclient/overview.html.

2. Samsung's ARM support for Xen, http://www.xenproject.org/developers/teams/arm-hypervisor.html.

3. Introduction to IPSEC VPNs on Mobile Phones, http://msdn.microsoft.com/en-us/magazine/ee412260.aspx.

4. Improving Xen security through disaggregation, http://dl.acm.org/citation.cfm?id=1346278.

5. Principals of Remote Attestation, http://dl.acm.org/citation.cfm?id=1989155.

KEYWORDS: virtualization, mobile phone, Android, cellular, data-at-rest, data-in-transit, data-in-use, IPSEC

AF151-040 TITLE: <u>On-Aircraft Cloud-Based App to Provide Enhanced EO/IR/SAR/Radar Sensor Exploitation</u>

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop applications (Apps) that can be implemented in an on-board open architecture computing cloud that utilizes small, low cost energy efficient processing; thus, enhancing the sensor exploitation capability of the aircraft sensor suite.

DESCRIPTION: Unmanned aerial systems (UAS) have grave limitations in the quantity and quality of data that can be transmitted either for end use or exploitation.

This SBIR effort seeks to develop and deploy one or more applications (Apps), similar in concept to those hosted on smart phones and within ground-based clouds, which can access this collected data, process it and then exploit the results using existing or newly developed algorithms. These Apps can enable discernment of various EO/IR/SAR/Radar issues that are only possible today through the use of powerful, ground based cloud systems after the UAS has landed and data has been downloaded. The output of such Apps will enable better, faster and more accurate use of existing and future EO/IR/SAR/Radar sensor systems. They will contribute to enhancements that enable more autonomous systems operations either in autonomy of sensor management or in flight operations. A secondary purpose would be to aid in sensor system health and maintenance functions. Although having a potential impact across numerous unmanned (and even some manned) systems, for the purposes of this topic, a relevant Air Force unmanned aerial vehicle (UAV) and its sensor suite configurations shall be the candidate demonstration system. The contractor will be expected to concentrate on the App(s) and not on an on-board cloud (hardware, real-time OS, and cloud controlling software) or on the interfaces to the sensors for control and data acquisition.

Issues that need to be addressed include (but are not limited to):
* The point where the App(s) will need to tap into the existing sensor data (raw, pre-processed, or processed, etc.) and the auxiliary data (navigation, antenna pointing angle, sensor control, etc.) flows to achieve the desired or advertised results.
* The method that will be used when in a bandwidth challenged or constrained scenario (internal or external), to prioritize which pieces of information/data that will be provided to the user in either real-time or near real-time and and what information/data must be buffered or stored for later delivery or use.
* The method that will be utilized to pass key information/data between the App(s) developed by this effort and other App(s) within the on-board cloud that will be consuming, moving or creating information/data.

* How internal App data flow rates will be handled.
* Algorithms or functions to be used as test cases to demonstrate the utility of the App(s).

PHASE I: The Phase I work will develop the App concept(s) and, as a minimum, examine the feasibility of the concept(s). If a single focused concept is proposed, as opposed to a “study of possible concepts” demonstration implementation can begin.

PHASE II: Phase II should include, as a minimum, development of a representative prototype concept capability to demonstrate the performance, security, feasibility, availability analysis, and non-disruption feasibility of the concept.

PHASE III: Military application: enhanced EO/IR/SAR exploitation capabilities will greatly contribute to better overall mission capabilities of systems. Commercial application: significant contribution to potential UAS operation in the National Air Space, as well as other applications.

REFERENCES:
1. "Sensing Requirements for Unmanned Air Vehicles: Engineers develop requirements and metrics to ensure integration of future autonomous unmanned aircraft into manned airspace," Tom Molnar, Bruce Clough and Won-Zon Chen; research published by AFRL Aerospace Vehicles Directorate, Wright-Patterson AFB, OH (VA-03-06).

2. "Evolution of Embedded Processing for Wide Area Surveillance," Courtney L. Usmail and Michael O. Little, Richard E. Zuber, IEEE A&E Systems Magazine, January 2014, p. 6-13.

KEYWORDS: autonomous sensing, sensor exploitation, dynamic resource management, contested environments, unmanned systems

AF151-041 TITLE: Decision Support Tool Using Gridded Weather Data

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop innovative ways of dynamically generating and assessing weather constraints on military operations and incorporating results within decision-support applications so as to afford the opportunity to mitigate and/or exploit weather affects.

DESCRIPTION: The Natural Operational Environment (NOE) includes ocean, land, air, and space. The NOE, hereafter weather, often obstructs coalition military operations from succeeding. In addition, because there are gaps between our abilities and our adversaries’ abilities to operate in weather (i.e., the weather delta), decision-makers want to plan operations to take advantage of the gaps where our forces can operate but our adversaries cannot and avoid the gaps where they can but we cannot.

This topic is focused on developing new software modules/services that dynamically ingest published weather data, generate constraints that the weather imposes on operations, and incorporate the resulting assessments/advice into decision-support applications. Air Force weather forces use computer-based weather modeling capabilities to produce uniformly gridded environmental analysis and forecast data sets for operational support. Recently, the Air Force Weather Agency (AFWA) has improved upon this process by consolidating the operational elements from multiple regional data sets into a single global data set and allowing human tailoring (modification) to correct key elements of the data set before it is made available for external consumption. However, the final step of tailoring this data to make it relevant to specific mission profiles has yet to be suitably automated.

Previous attempts to implement an environmental impact decision support tool have resulted in the creation of a Rules Encoding Application (REA) that provides an acceptable means of encoding, modifying and managing weather sensitivities of military capabilities. The contractor will investigate leveraging REA, the Weather Data Analysis (WDA) Intelligent Data Services (IDS), as well as other technologies for implementing weather sensitivity thresholds. The Government is looking for recommendations on a way forward for incorporating REA rules into automated decision support processes.

This solicitation requests the design, development, delivery, and demonstration of service- based environmental decision support capabilities that support the planning and execution of Air Force operations. The design will take into consideration the deployed systems that will use the tool, including the Joint Environmental Toolkit (JET), Mission Planning Weather (MPW), AFWA Weather Data Analysis (WDA), Operational Data Layer (ODL), and Air Force Weather Web Services (AFW-WEBS).

It is expected that, as a result of this effort, new, innovative capabilities will be devised, tested, and included in modules/services which can be employed to seamlessly incorporate weather impact advice within decision-support tools/ applications/ systems, which includes Air Force weather systems listed above. Figures of merit in assessing effectiveness include verification and validation of algorithms, ease of integration, ease in understanding advice that is presented, and enhanced probability of mission success.

The successful offeror may work with the technical point of contact to identify scenarios and acquire interfaces and sample data from the JET, MPW, AFWA WDA, ODL, REA, and AFW-WEBS. Phase II winners will be provided access to live data services.

PHASE I: Conduct research, glean knowledge from subject matter experts, and design revolutionary ways of generating and incorporating weather risk management/advice into active, agile command and control applications within high tempo, dynamic environments. Develop approaches for determining technical feasibility. Investigate and employ AFWA's operational services (listed above).

PHASE II: Perform detailed analyses of how resulting weather advice adds measurable value, and demonstrate the efficacy of those algorithms and processes within specific use cases. Demonstrate modules within existing or prototyped decision-support tools using real-world data sets garnered from operational weather web-services.

PHASE III: Results will be useful in any C2 application that involves the planning of events affected by weather whether they be in military ops (e.g., attack, air refueling), government operations (e.g., FAA, disaster recovery), or commercial applications (e.g., sporting events, transportation, agriculture).

REFERENCES:
1. Heckman, Scot T., 2008: Integrating Weather in Net-Centric Warfare-A Case for Refocusing Human Resources in Air Force Weather, Air & Space Power Journal, Vol. 22, No. 1, Spring 2008. http://www.au.af.mil/au/afri/aspj/airchronicles/apj/apj08/spr08/heckman.html.

2. Joint Publication 3-59, Meteorological and Oceanographic Operations, 07 December 2012. http://www.dtic.mil/doctrine/new_pubs/jp3_59.pdf.

3. Shirkey, Richard C., and Melanie Gouveia, 2002: Weather-Impact Decision Aids: Software to Help Plan Optimal Sensor and System Performance, Cross Talk The Journal of Defense Software Engineering, Software Technology Support Center.

4. Farrell, Robert J. Jr., Loomis Jeremy, Desai, Chetan, and Duncomb, Robert, 2009: Weather Effects Embedded within Net-Centric C2 System Workflows, 14th ICCRTS C2 and Agility, Topic 10: Collaborative Technologies for Network-Centric Operations, June 2009. http://www.dodccrp.org/events/14th_iccrts_2009/track_10.html

KEYWORDS: rule-based-decision-support, gridded-environmental-data, ODL, weather, weather impact,mission constraints

AF151-042 TITLE: Hierarchical Dynamic Exploitation of FMV (HiDEF)

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop techniques for machine-aided visual search & recognition in full motion video (FMV) from moving aerial platforms.

DESCRIPTION: Techniques are needed to bridge the gap between the low-level image pixel data and the higher level, semantic content obtained from textual sources to allow correlation and fusion of the two, thus resulting in more effective, faster imagery analysis.

Manually searching through unstructured video for specific content is a human-intensive process. In order to reduce this human intensive task, innovative machine-aided techniques are sought for searching FMV content for specific objects of interest. This is a high-interest technology for Air Force Special Operations Command and is crucial to enable the command to handle an increase in remotely piloted aircraft orbits. By automating search, collection and correlation with man-on-the-loop, this technology will facilitate better situational awareness at machine speed and help focus the imagery analysts' attention on analysis rather than on gathering data.

Current machine-aided image and video processing techniques work well with high resolution data where pixel information alone is sufficient for deriving higher level content. However, much of the operational data of interest is of low resolution quality, which makes identifying likenesses of images very difficult using known methods. When humans analyze imagery, they incorporate prior knowledge and experience to understand the scene, which is not usually employed in current machine-aided image search techniques.

Biological organisms are extremely efficient at making sense of sparse, noisy, and uncertain visual information. The coordinated activity of cortical and subcortical brain circuits gives organisms the ability to perceive their environment, plan and act upon it, and progressively build stable representations of behaviorally relevant objects in the external world via synaptic plasticity. To achieve these goals, biological brains make use of massive parallelism and have a dynamic hierarchical organization. One of the apparent consequences of this type of organization is attention (i.e., feature attention, spatial attention). The dynamic nature of the system results in significant amount of feedback in all of the processing stages, changing the expectations of perception and continually updating the world model. Emulating the biological systems may be one approach to improve performance of current image search techniques.

The Air Force Research Laboratory is researching machine-aided capabilities to find, identify and characterize objects of interest across multiple information sources. A semantic reasoning framework can be used to reason over human reported textual content, but there are no automated methods to incorporate the massive amounts of unstructured FMV content into this framework. This leaves a large source of information underutilized, except only if extraordinary human efforts are made to manually review archived FMV or if the object of interest has previously been reviewed and reported on. We are looking for innovative solutions to help resolve this technology shortfall. Any automated or machine-aided techniques to lessen the human burden of having to manually search through hours of FMV for specific objects of interest will be considered for this topic. FMV data will be provided for verification of algorithms.

PHASE I: Develop innovative concepts and techniques for automatic, or machine-aided search of FMV. A confidence metric should be part of the output. Concepts should be verified using relevant data.

PHASE II: Develop a prototype system or subsystem demonstrating the techniques for automatic, or machine aided search of FMV. The prototype will be tested on operational data to evaluate its utility.

PHASE III: Transition the technology to the Air Force exploitation and fusion systems. Potential Phase III customers include Air Force operational units, Air Force Life Cycle Management Center, Law Enforcement, Drug Enforcement Agency and prime contractors such as Northrop-Grumman and Lockheed-Martin.

REFERENCES:
1. Hebb D. The organization of behavior. (1949). Wiley, New York U.S.A.

2. Hu H., Xie N., Li L., Zeng X., Maybank S. (2011). A Survey on Visual Content-Based Video Indexing and Retrieval. IEEE Transactions on Systems, Man, and Cybernetics, 41(6), 797-819.

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4. Versace M., Ames H., Leveille J., Fortenberry B., and Gorchetchnikov A. (2008). KInNeSS: A modular framework for computational neuroscience. Neuroinformatics, 6(4), 291-309.

KEYWORDS: computer vision, dynamic systems, visual perception, biologically inspired, video indexing, content based image retrieval, FMV

AF151-045 TITLE: Safety Critical Implementations of Real-Time Data Distribution Middleware

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: The objective of this research is to create a safety critical implementation of a real-time distributed network communications and data distribution middleware library with the capacity to service several hundred publishers and subscribers.

DESCRIPTION: Real-time data distribution middleware such as implementations of the Object Management Group (OMG) Distributed Data Service (DDS) standard or the open source ZeroMQ project enable flexible network systems architectures, data distribution across such networks, and the maintenance of consistency and concurrency of such data across a network. The capabilities of such middleware to support redundancy and synchronization for data distribution have made them candidates for use in safety critical systems. However, although commercial implementations of some products are available, they are generally not certified for safety critical use. Such real time assured data distribution and system reconfiguration capabilities would be valuable in force reconfiguration, testing, training, and other uses. The software must be suitable for use on a long haul network with imperfect communication links and have general purpose application programming interfaces (APIs) suitable for at least one and preferably multiple general purpose language. Phase I work would Propose a mature real-time data distribution middleware implementation, show that it can be safety qualified in accordance with a safety standard in wide use such as IEC 61508 (CIL 4), RTCA DO 278A (Level 1), RTCA DO 178C (Level A), or IEEE 12207 (Level 4), demonstrate its capability of supporting up to 200 nodes with 1000 objects with the capability to automatically reconfigure and maintain data consistency in the presence of network and processor failures, and Prepare a development plan for (1) a safety critical implementation and (2) a documentation package for safety qualification. It would show the feasibility of creating an implementation of such a library that could satisfy the requirements of an industrial standard used in a safety critical industry. It would also include a development and test plan to implement the safety critical software in Phase II. Phase II work would actually implement the software.

PHASE I: Propose a mature real-time data distribution middleware implementation, safety qualified to afformentioned standards, demonstrate supportability of up to 200 nodes with 1000 objects with auto-reconfigure capability and data consistency in the presence of failures. Prepare a development plan for (1) a safety critical implementation and (2) a documentation package for safety qualification.

PHASE II: Develop, test, and document the implementation in accordance with the plan described in Phase I.

PHASE III: Military Applications: All networked systems where reconfiguration is required including unmanned aerial systems (UASs), ground vehicles, ships, and aircraft.
Commercial Applications: Wide spread, including UASs, automotive, medical, and many other implementations.

REFERENCES:

1. Distributed Object Computing Group (DOC) for Distributed Real Time and Embedded Systems, http://www.dre.vanderbilt.edu/.

2. Distributed Real-time and Embedded (DRE) Systems.

3. Zeromq web site: http://zeromq.org/.

4. Pieter Hintjens, "ZeroMQ: Messaging for Many Applications," O"Reilly Media, March 2013.

5. Opendds web site: http://www.opendds.org/.

6. Object Management Group DDS portal: http://portals.omg.org/dds/.

KEYWORDS: middleware, real-time distributed systems, fault tolerance, publish-subscribe, data distribution, safety critical software

AF151-047 TITLE: Electronic Warfare Battle Manager Situation Awareness (EWBM-SA)

TECHNOLOGY AREAS: Electronics

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OBJECTIVE: Develop and demonstrate innovative software capabilities to increase the commander's situation awareness of the electromagnetic spectrum (EMS) to enhance resiliency of distributed control.

DESCRIPTION: According to Air Force Doctrine Document 6-0, command and control (C2) of air, space and cyber forces requires "the exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission." For the Air Force to accomplish its mission in the cyber domain, the properly designated commander, typically the Joint Force Air Component Commander (JFACC), must be able to direct and control actions operating within the electromagnetic spectrum.

Without it, intentional or unintentional actions by red, gray, and even blue forces will quickly neutralize U.S. advantages in net-centric weapons and the benefits gained through the Global Information Grid. Electromagnetic spectrum management is a term describing the blue force effort to apportion, allocate and schedule the electromagnetic spectrum. The output of the process is the Joint Restricted Frequency List (JRFL), which is designed to identify key blue frequencies and minimize electronic fratricide. The JRFL is a staff-oriented planning process not easily adaptable to dynamic combat operations and cumbersome to adjust. While spectrum management tools have improved significantly over time, the end result is still a relatively static legacy product providing little operational and tactical ability to plan and dynamically adjust operations in the electromagnetic spectrum to prepare for, react to, or preempt enemy use.

Novel approaches are sought to allow the Air Component Commander and his/her staff to dynamically view and understand the status of blue air Electronic Attack (EA) assets and the red Enemy Order of Battle (EOB) through Link-16, intelligence feeds, propagation models, constraints, etc. to provide the first step towards understanding the EMS threat environment in an integrated tool. The tool when completed needs to highlight where blue, red, and gray efforts will potentially conflict and identify closest points of approach to avoid interference.

The commander considers options to deny red and/or gray use and adjust/time-phase blue use. It must also identify where simultaneous use by all sides conflict. For example, service-oriented applications need to enable a commander's staff to plan tasks such as emission control (EMSEC) to provide quick look-through windows during the key seconds a net-enabled precision weapon needs an update. Once the plan is executed, commanders also need to assess if plan deviations adversely impact blue objectives, or provide unacceptable red advantages.

The successful offeror may work with the technical point of contact (TPOC) to identify scenarios and acquire data for concept development. For example, there is ample information about the JRFL on-line but the TPOC can provide redacted samples.The Government will provide sensitive unclassified data, information and environment details to support Phase II proposals.

PHASE I: Generate realistic concepts and relevant use cases to assist in the analysis and identification of promising technologies that enable situational awareness and management of the electromagnetic spectrum in contested environments. Analyze the potential solutions and develop a design concept of selected technology; prototype demonstration is a bonus.

PHASE II: Develop, demonstrate, and validate a prototype with relevant vignettes. Identify transition opportunities, and prepare a plan to validate the technology in a realistic command and control environment (Technology Readiness Level 5). Specific results will be relevant only to military operations, but the methodology and algorithms will be immediately applicable to a wide variety of commercial frequency management problems.

PHASE III: As new weapons, including cyber domains and integrated unmanned and manned platforms, enter the Air Force inventory, a method to understand and dynamically control the electromagnetic spectrum at the tactical edge will be required. Initial transition target is the Air Operations Center.

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KEYWORDS: command and control, electromagnetic spectrum, situation awareness, measures of performance, measures of effectiveness, electronic warfare, EW

AF151-048 TITLE: <u>Cognitive Augmentation for Distributed Command and Control</u>

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop information technology which fuses distributed sensing and human perception to increase operator situational awareness and decision speeds for controlling complex, highly dynamic networks.

DESCRIPTION: Recognizing and effectively responding to sudden events is a challenge faced by decision makers across all levels of command. Network attacks in particular can stress the abilities of operators to maintain key functions essential to mission accomplishment. Even with support from distributed experts and varying levels of human-machine collaboration, defensive measures can seriously lag behind the sub-second speed of such attacks. Whether in-the-loop or on-the-loop, human operators need a rapid and concise portrayal of the situation that is tuned to their natural cognitive skills. A key input will come from networked sensors and "big data" computing techniques, which can establish a "remote presence" essential to accurate understanding of the situation. The resulting information must then be translated and displayed to mesh with innate human perceptual abilities, forming a seamless path from event to understanding. This initiative will develop such technologies, which augment human situational awareness for geographically distributed teams. It will combine advances in several fields of knowledge including cognitive science, machine learning, and visualization with expertise from the command and control realm to provide a new generation of highly resilient command and control systems.

PHASE I: Design and develop a multi-faceted representation for complex network environments that melds information gathering with a wide range of innate human perceptual abilities.

PHASE II: 1) Build a prototype that implements the Phase I representation, and demonstrate it for realistic domain or network scenarios. 2) Determine appropriate performance metrics, and evaluate the prototype against a legacy system. 3) Plan for the Phase III effort and eventual transition of the cognitive augmentation technology to customers.

PHASE III: This research would enhance network operations for DoD information technology systems, with potential extension to integrated command and control systems for synchronizing air-space-cyber operations.

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KEYWORDS: remote presence, situational awareness, decision support, distributed command and control, human perception, visualization

AF151-049 TITLE: Normality Modeling and Change Detection for Space Situational Awareness (SSA)

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of

sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Research and develop a system to automatically learn normal behavior of human-made, space-based objects and detect changes in their behavior.

DESCRIPTION: At present there are upwards of 10,000 known man-made objects orbiting the planet Earth. These objects range from satellites that are under positive control, to failed satellites, to space junk or debris. The U.S. Air Force and international agencies actively monitor these objects to provide early warning of potential threats or collisions so that owner/operators of the satellites can take measures to avoid a collision and loss of a satellite. Even very small objects can cause great damage, and a collision or breakup of a satellite results in even more space debris to monitor. As new telescopes and other space surveillance assets come on line, the number of objects that can be detected is rapidly increasing and will exceed the ability of space management resources (human and machine) to monitor and analyze satellite status and "behavior." As a result, there is a need for innovative and automated analysis capabilities that can capture or learn the normal status and behavior of satellites, detect changes, and assess the implications of those changes.

Developing such capabilities requires addressing several challenges:

• Developing and/or learning motion-based normalcy models which incorporate orbital mechanics and space-based phenomena;

• Addressing the objects' life cycles in the normalcy models (i.e., from launch, through deployment, mission, and end of mission);

• Managing position and identification uncertainty in the modeling framework; and

• Using the normalcy models to predict behavior and detect anomalies in a timely manner and with a low false-alarm rate.

Motion-based pattern learning and change detection efforts do not always incorporate life cycle behaviors, or deal with significant uncertainty in location or identification. In the space setting, however, understanding the life-cycle behavior of a satellite is expected to be a key element of normalcy models, as well as incorporation of physics-based models, and is expected to help address the data uncertainty and data scarcity challenge.

This topic is seeking to develop a set of algorithms within a service oriented based architecture (SOA) that can be used to (semi-)automatically develop normalcy models for space-objects, predict expected behavior, detect and assess deviant or anomalous behavior, and alert operators to developing or potential threats, collisions and/or problems. The resulting system will be used to support expanded space situation awareness to provide information about the current and predicted location of large numbers of space objects and provide alerts about potential threats. The resulting information will be used in space planning, including launch of new satellites.

PHASE I: Design and deliver a methodology and architecture. Define system architecture requirements in terms of model performance (prediction accuracy, probability of anomaly detection and probability of false alarm). Define metrics for analyzing system performance. Deliverables include a system architecture design, block diagram identifying data flows and interfaces, and a technical report.

PHASE II: Develop a prototype system based on the architecture defined in Phase I to model and/or learn the normal behavior of space-based objects, predict future behavior, detect anomalies, and provide alerts. Develop and implement a plan to test and measure the performance of the system.

PHASE III: Scale up the Phase II system to handle the expected system load. The resulting system will support space situation awareness, for military organizations (JSPOC, NASIC, NRO, AFSOPS) and commercial satellite owner/operators.

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KEYWORDS: pattern learning, change detection, anomaly detection, machine learning, space situation awareness, adaptive learning, statistical modeling

AF151-050 TITLE: Advanced Detectors for Long Wave Infrared (LWIR) Communications

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Provide a very high sensitivity (D*> 1013), high bandwidth (>1 GHz) detector technology with a peak wavelength response between about 8 to 11 microns for use in free space laser communications.

DESCRIPTION: Although clear air attenuation at either of the legacy SWIR and LWIR bands is very good, propagation through reduced visibility conditions caused by precipitation, haze, dust, and fog is significantly better at the longer wavelengths, mainly due to reduced scattering resulting from the larger wavelength to aerosol particle size ratio. Turbulence-induced scintillation losses are also greatly diminished at the longer wavelengths, thus reducing or eliminating the need for wave-front correction and other techniques required to overcome this additional problem. Recent increased demand for moderate to long range communications at extremely high data rates, and the growing lack of available RF bandwidth has resulted in the deployment of several new SWIR based systems, and has generated renewed interest in the LWIR spectrum to provide higher link availability in reduced atmospheric visibility conditions. Fortuitously, new component developments in the LWIR spectrum are now, for the first time, enabling practical implementations of communications systems operating at these wavelengths. The most dramatic and impressive of these has been in the area of Quantum Cascade Laser (QCL) sources. Compact, multi-watt QCL lasers, which can be directly modulated at GHz rates, are now available off-the-shelf. These devices provide essentially the same Size, Weight, and Power (SWAP) advantages and functional capability as their SWIR laser diode and ER-fiber amplifier counterparts, but in the LWIR spectrum. Much technological progress has also been made on the receiver/detector side as well, but there is still a performance gap between the best LWIR and SWIR detector technologies in the general area of detector sensitivity, with the latter having an average advantage of 10 dB or more (maximum D* for LWIR approx 1013, maximum D* for SWIR >1014). Even with this receiver sensitivity limitation, operation in the LWIR spectrum offers a tremendous potential system advantage since even a slight degradation in atmospheric visibility can result in additional path losses of greater than 2 to 3 dB/Km in the SWIR spectrum. A number of new LWIR detector technologies have been explored and developed over the last few decades, including QWIP, Quantum Dots, and other variants of these. However, simpler bulk devices utilizing the older MCT technologies still provide the highest performance to date. (This is not to say that examination of the other technologies should be excluded, since the goal of this effort is to provide for the best possible near term solution in any form.) The most interesting new development of which we are aware appears to be the Electron Avalanche Photodiode (EAPD). These devices are reported to have the unique ability to provide orders of magnitude gain in the detector without the generation of additional detector noise. This would appear to create the same effect as receiving (or having transmitted) a corresponding larger signal, and thus providing for a correspondingly larger signal to noise ratio, or better receiver sensitivity. Therefore, the overall goal of this effort will be to identify and build upon one or more of the most promising existing or emerging LWIR detector technologies to provide a near term (1 to 3 years) LWIR detector solution which has optimum sensitivity (D*), bandwidth of at least 1 GHz, and operates at the highest possible temperature. Note that the latter criteria is the least important since cryogenic operation via micro-cooler hardware is a mature and highly reliable technology.

PHASE I: Investigate existing technologies, and develop/analyze one or more optimum performance single element LWIR detector solutions that could provide for high speed, high sensitivity receiver operation for free-space laser communications, with the possible demonstration of an actual near-term candidate device as an interim proof-of-concept product.

PHASE II: Fully develop, fabricate, and characterize one or more optimized LWIR detector designs based on the Phase I effort, and demonstrate the technology in an actual deliverable LWIR receiver configuration.

PHASE III: DoD & Commercial apps could get a successful product & Phase III transition paths could be pursued. High availability "all-weather" optical communications for DoD: Low Probability of Intercept, high capacity sensor downlinks, & short/medium range trunking for commercial terrestrial communications.

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KEYWORDS: Long-Wave Infrared communications, LWIR, LWIR detectors, HgCdTe Detectors, MCT, EAPDs, QWIPS, Quantum Dot detectors

AF151-051 TITLE: <u>Built in Test (BIT) Capability for Multi-Mode (MM) Fiber Data Networks</u>

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop built-in-test (BIT) functionality for fiber optic transceivers that allows insitu measurement of link-loss and internal transceiver parameters for prognostics and health management suitable for embedding into aerospace fiber optic networks.

DESCRIPTION: Current airborne platforms are increasingly taxed to deliver critical information for everything from mission system sensor information to position and navigation information. Fiber optic data communication are used to achieve increased performance at reduced power consumption and electromagnetic susceptibility. The typical military aerospace environmental conditions create potential for fiber optic link degradation or failure. A poor quality or failing link has immediate & limiting impact to the platforms ability to accomplish the mission. Diagnostics & repair often take extensive amount of time and manpower. Typical fiber links lack systems for monitoring the fiber cable plant for degradation or faults due to connector contamination or damaged optical pathways.

Fiber optic systems with integrated methods of monitoring the cable plant and precisely locating faults have significant potential to reduce the total cost of ownership and improve the availability of the fiber networks over the asset life cycle. Avionic networks typically rely on a central switch to coordinate network traffic. This switch has optical connections to remote nodes on the aircraft. Therefore, by incorporating cable plant monitoring technology into the central switch, the entire network will fault monitoring and diagnostics.

An important benefit from such a system that could exchange status and health information would be the ability to auto-negotiation the link data rate to optimize data throughput. The demands of improving sensor systems and the need to utilize legacy network require the smart and efficient use of the length-bandwidth limit that the fiber plant can support. With the drive towards higher data rates, a system that enables 10 Gbs at a minimum is required.

The extreme environments of airborne platforms pushes the limits of current fiber optical networks and leads to many potential ways for a link to fail, from reduce link margin, fiber breaks, laser source current draw and even dirt egress which reduces received signal strength. A system that monitors the system health to a degree to be useful in understanding the failure or potential link failure mechanism is of great benefit to the warfighter. Fiber optic transceivers with embedded optical time domain reflectometer (OTDR) and link-loss BIT present an opportunity for real time monitoring and fault isolation. A monitoring system, when incorporated with prognostic and health management (PHM) approaches and software, can enable comprehensive condition and health indicators.

Compatibility with legacy airborne platforms is greatly desired. These platforms typical are cabled with 50 micron OM2 MMF and 100 micron MMF. In addition, new technologies which could enable better performance while maintaining a drop in replacement capability will be considered. The system would naturally need to be able to survive extreme temperature and vibrations (MIL-STD-810, MIL-STD-883). As such smaller packaging would be beneficial and would likely free up needed PC board real estate.

Technology development is required to achieve integration of fiber network prognostic capability into avionic systems. This research will investigate the strategy of measuring baseline heath and normal operation, network degradation, and deviations from normal. The developed algorithms must be compatible with autonomous operation, without impact to the existing aircraft processing capabilities.

This topic seeks an innovative switch architecture that incorporates cable plant monitoring, while minimizing the production cost and without sacrificing network performance and scaling. The developed solutions will need to meet the performance requirements of military standards for environmental ruggedness.

PHASE I: Perform trade space analyses of candidate technologies. Identify and design BIT architectures and prototype proof - of - concept devices to give an indication of success of Phase II. Phase I: 1) investigate methods of measuring fiber cable plant health, 2) develop a plan to characterization cable plant failures in an aircraft environment and 3) propose an approach central switch integration.

PHASE II: Perform detailed design and implementation of a BIT-enabled 10 Gbps (min.) bandwidth multi-mode fiber link that implements health status monitoring for at least 4 states and a minimum of 32 ports for the architecture developed during Phase I. Develop software algorithms for demonstrating automated reporting of fiber plant health and prognostics. Test the prototype in relevant military avionics cable plant environment. Characterize the prototype for possible Phase III transition.

PHASE III: The contractor will develop a BIT-enabled, high bandwidth fiber link for military/commercial aircraft and other platforms. Affordability will be a key focus for this application. A partnering with a commercial supplier can be established to ensure the transition.

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KEYWORDS: avionics, optical, built-in-test, BIT, fault isolation, prognostics, fiber-optic communication

AF151-054 TITLE: <u>Airfoil Sustainment Through Automated Inspection and Repair</u>

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual

use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop an innovative low-cost process to perform automated 3-D inspection and crack inspection of airfoils in order to facilitate implementation of established repair requirements.

DESCRIPTION: As legacy propulsions systems in the U.S. Air Force mature, the requirement to implement cost-effective inspection and repair of low-cost recoverable engine airfoils is a goal for the propulsion enterprise. To reduce the existing airfoil supply chain footprint, efforts should be taken to establish an innovative integrated low-cost, high-volume inspection and repair capability, with a goal of utilizing used parts which fall within the established serviceable and repairable limits.

Large quantities of low-cost airfoils, such as small, inserted titanium and nickel compressor blades, are being automatically condemned and scrapped after limited service, due to failure of inspectors to perform sanctioned inspections necessary to determine serviceability and repairability of these items. This lack of inspection or repair is due to the relatively low cost of the airfoil parts versus the cost of the inspection and repair the individual airfoils.

The proposed inspection system must be capable of processing up to 143 different part numbers, approximately 190,000 parts per year. Inspection systems must have a high probability of success in performing dimensional analysis and inspection of airfoils for the presence of cracks. Airfoils that do not meet documented dimensional requirements or flaw size limits cannot be reintroduced into an engine under any circumstance (e.g., Type II errors are unacceptable).

The current airfoil inspection processes uses fluorescent penetrant inspection (FPI), for crack determination. Calipers along with go-no go gages are used for dimensional inspection of cord width and tip wear. Any proposed methods should meet or exceed crack detection capability of FPI. Dimensional inspection requirements are on the order of 1 mil (.001 inch).

To successfully perform the work described in this topic area, offerors may ask to use unique equipment/data in the possession of the U.S. Government located at Tinker Air Force Base, Oklahoma, during the Phase II effort. Accordingly, the following items of base support may be provided, on a no-charge-for-use basis, to the successful offeror, subject to availability: The equipment/data includes compressor airfoils with geometric tolerance inspection specifications as well as flaw size requirements.

The current authorized airfoil repairs include minor blending and shot peening.

An alternate more cost effective and innovative approach to perform these inspections are sought, as the current technology used within the Air Force to inspect and repair these airfoils has become antiquated and environmentally unfriendly due to the use of chemicals in the FPI process.

Opportunities may exist in the commercial industry which can be used to update existing Air Force inspection capability. The Air Force is seeking to implement an automated part-handling and inspection station which has the capability to integrate these two inspections technologies into a unitized robotic inspection system. The automated robotic part-handling and inspection system must pass demonstration and validation requirements for these capabilities in a production environment for the suite of airfoils identified by the Air Force.

PHASE I: The contractor must provide a plan which will be used to develop and demonstrate the feasibility of the stated objective, which is to develop an innovative low-cost, high-volume automated part-handling and integrated inspection station for propulsion airfoils. The concept design will be compatible with the current depot level maintenance facilities and capable of processing requirements.

PHASE II: Previous data will be used in Phase II to determine most cost effective hardware and software to be used in the design of prototype which will be constructed in Phase II. The SBIR contractor must design and develop a prototype capable of demonstrating requirement objectives as defined in Phase I. During Phase II the contractor will capture prototype performance data and generate a detailed plan for implementation of production level hardware and software, which will be used in Phase III.

PHASE III: During Phase III, applicability to military engine maintenance at the depot level will be demonstrated.

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KEYWORDS: airfoil, sustainment, automation, inspection, repair, part-handling

AF151-056 TITLE: Next-Generation All-Electric Aircraft Auxiliary Power Unit (APU)

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop and demonstrate a high efficiency (25-plus percent), high-power-dense (150 W/kg) all-electric on-board aircraft APU for high-altitude (up to 65 kft mean sea level (MSL), long-range unmanned aerial system (UAS) operations.

DESCRIPTION: UASs have become an essential asset for U.S. military forces, and increasingly by allied forces, to help establish battlefield superiority in today's hot zones, allowing for more precise weapons targeting and better protection over friendly forces. The use of these weapon systems have, and continue to provide, unparalleled real-time information to the ground forces to support both the Global War on Terrorism and humanitarian relief missions. However, as the use of these vehicles continues to expand into new and ever-changing mission sets that require more power from the integration of advanced sensors, the electric power subsystem is quickly becoming over-burdened and limited in supporting both current and future CONOPS. The goal of this topic is to directly address this power and energy limitation to support future high-altitude, long-range UAS missions through the development of an all-electric (i.e., advanced battery or fuel cell power system) auxiliary power system to support nonflight critical on-board electrical power needs. The high-efficiency APU may provide on-board electric power, either in support of a dedicated subsystem or a combination of subsystems as needed, for such functions as in-flight deicing, landing gear thermal management, and/or current and future sensor payloads. The power system must be able to sustain reliable operation in the net electric power range of 2 to 10 kW over the entirety of the mission which can last up to 24 hours in length, with a gravimetric system power density of 100 W/kg threshold, and a 150 W/kg objective (not including fuel, if an external fuel source is required), at a minimum 25 percent electrical efficiency. Deployment requirements may dictate that the UAS operate in environments which include operation at high altitudes (up to 65,000 feet MSL) and/or wide operating temperature range of -70 degrees C to +60 degrees C (-54 degrees C to +70 degrees C non-operating). The all-electric power system designed under this topic shall demonstrate a path to accomplishing operation in this environment as part of the design. Additionally, the power system should be able to operate on on-board fuel to be consistent with the UAS operational requirements, therefore minimizing logistic footprint and potentially allowing for a common fuel tank to be utilized.

PHASE I: Design an advanced all-electric power system APU concept capable of supporting on-board UAS operations described above. Define performance parameters/interface constraints. Demonstrate feasibility through modeling and simulation and/or scaled bench tests that the system has a sufficient power/energy-density and electrical efficiency to meet design metrics while operating on on-board logistic fuel.

PHASE II: Develop advanced power system designed during Phase I with a focus on direct utilization of logistic fuels consistent with UAS operations at the required performance metrics. Address performance/interface constraints identified in Phase I. Demonstrate that the APU power system is capable of producing sufficient electrical power for reliable operation over the 24-hour mission duration (threshold) in a simulated operational environment (objective).

PHASE III: Military applications include on-board APU power support for intelligence, surveillance and reconnaissance (ISR), target tracking and acquisition missions. Commercial applications include onboard power support for commercial aircraft and humanitarian relief missions.

REFERENCES:
1. Eelman, Stephen, et al., Fuel Cell APU'S in Commercial Aircraft – an Assessment of SOFC and PEMFC Concepts, 24th ICAS Proceedings, Yokohama, Japan, (2004).

2. FY 2009-2034 Unmanned Systems Integrated Roadmap, http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA522247 (2009).

3. Gertler, Jeremiah, U.S. Unmanned Aerial Systems, Congressional Research Service report for Congress, http://www.dtic.mil/dtic/tr/fulltext/u2/a566235.pdf (2012).

KEYWORDS: aircraft auxiliary power unit, APU, unmanned aerial vehicle, fuel cell, SOFC, PEMFC, metal air battery

AF151-058 TITLE: Calculated Air Release Point (CARP) Navigation Update Due to Ground Effects (NUDGE)

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a tool to support Air Force airdrop operations. This tool will exploit data from past airdrops to the same location to enhance the planned flight path and air release point calculations, while compensating for localized effects.

DESCRIPTION: Future airdrop operations must be consistently accurate, cost efficient, and measurable. The Air Force needs to airdrop payloads within 150 m of the impact point from high- and low-altitude environments. Airdropped items that miss their mark create risk of exposure to ground recovery teams, while lost/damaged bundles can be costly to replace. Wind measurements are used to reduce error substantially. At some locations, however, bundles have tended to skew in one direction over another, due to terrain features shaping the wind vectors. Variations in terrain can affect the flow of boundary layer winds and obscure the visibility of ground threats. Air and ground-based threats can affect the safety of the aircraft and even successful delivery of the bundles. To mitigate such threats, a pilot may be limited to flying a very constrained safe corridor to the drop zone (DZ).

The approach to the DZ may vary from mission to mission due to ground threats, weather, fuel, topography, or pilot discretion. Variances in the aircraft's approach to the DZ could be minimized via a navigation aid that directs the pilot (or autopilot) regarding which route to fly. Variances between flight crews could be minimized by self-correcting over multiple drop missions, making minor adjustments to the flight path to compensate for changes in the operational environment. These corrections could be computed automatically in real-time and regularly updated with data from prior airdrops. Machine learning could even be applied as part of the path planning solution at a particular DZ to identify trends in drop trajectories. Mission data could be recorded as it is being collected for use in future flight path calculations.

The desire is to develop a solution that will automatically input accumulated information from prior flight and airdrops, anticipate the bundle trajectory, and converge on a navigated path for a cargo aircraft to perform the air drop missions. The data assimilation process shall exploit historical data from the same drop site, terrain, obstacle, and current intelligence threat data in order to produce a flight path and an adjusted Calculated Air Release Point (CARP) that compensates for localized effects to improve overall accuracy. Sample historical data will be provided by AFRL for initial analysis in Phase I. Historical data may include aircraft location and orientation at the time of release, planned and actual release/impact points, time of day, aircraft weight, bundle weights and trajectories, and weather forecast. Based on the variables described above, preliminary investigations should determine whether cargo drops really are subject to a statistically significant bias, and if feasible, determine whether these biases can be identified and compensated for in a consistent manner.

Proposals are expected to address data assimilation in a holistic manner, identifying whether and how data analysis can iteratively improve the calculated release point and the path flown to reach it. It is important that the flight corridor be part of the solution so that the adjusted CARP will be on that path, and so that the approach can be controlled. Computed flight paths should be converted into a visual navigation aid which shows the boundaries of the airspace corridor to be flown, probabilistic limits of the release point, and any necessary adjustments for the aircraft. Demonstration of the improvement in CARP calculations should be shown through the use of physics-based modeling.

PHASE I: Investigate the feasibility of using prior airdrop data to improve airdrop operations. Develop a conceptual tool to plan flight paths and a CARP, considering prior results. Apply physics-based modeling to predict bundle landing locations. Use intelligent data analysis techniques (e.g., machine learning) to identify trends that can be exploited for CARP improvement. Demonstrate in simulation.

PHASE II: Provide a practical implementation of the techniques from Phase I. Extend the CARP NUDGE solution for application to multiple aircraft including C-130H, C-130J-30, and C-17 aircraft. Verify increases in airdrop point of impact accuracy. Model drop trajectories both before and after applying the CARP NUDGE solution.

PHASE III: Potential military applications include precision airdrop and C-130 water drops. Potential commercial applications include aerial delivery of supplies and materials to remote locations to support disaster recovery, construction, utilities, postal services, luxury cruises, and adventurous tourists.

REFERENCES:
1. Bennett, Andrew W., "Design of a Precision Airdrop System," American Institute of Aeronautics and Astronautics, Inc. (1997): 97-1469. Web. http://arc.aiaa.org/doi/pdf/10.2514/6.1997-1469.

2. Ward, Michael, Mantalvo, Carlos and Costello, Mark, "Performance Characteristics of an Autonomous Airdrop System in Realistic Wind Environments," AIAA Atmospheric Flight Mechanics Conference (2010): 2010-7510. Web. http://arc.aiaa.org/doi/pdf/10.2514/6.2010-7510.

3. Wright, Robert, Benney, Richard and McHugh, Jaclyn, "Precision Airdrop System," 18th AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar (2005): 2005-1644. Web. http://arc.aiaa.org/doi/abs/10.2514/6.2005-1644.

KEYWORDS: precision, airdrop, airdrop accuracy, machine learning, computed air release point, CARP, terrain, real-time wind, airdrop modeling, aircraft navigation, airdrop simulation, navigation, cargo airdrop, mobility airdrop

AF151-059 TITLE: Advanced Component Cooling Design and Evaluation for Gas Turbine Engines

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: To improve the design of high-pressure turbine (HPT) components for increased efficiency and extended turbine life and to enable thorough, rapid validation of new designs through a combination of physics-based analysis and high-fidelity testing.

DESCRIPTION: For future gas turbines, it is desirable both to increase performance and to reduce operating costs. While turbine performance increases are achievable through increases in turbine inlet temperature, this often results in decreased turbine durability. Since designers currently rely primarily on an experience-based approach, there is a durability margin that is built into the design of turbine components (for example, blades and vanes). Consequently, component life estimates can be either over-predicted or under-predicted. If part life is greater than predicted, then turbine components are using more than the optimum amount of cooling, and the performance of the overall system is reduced concomitantly. However, if part life is less than predicted, then the system requires more frequent inspection coupled with possible repairs and/or part replacements. This inevitably results in increased life-cycle costs as well as reduced readiness of the armed forces. Further, turbine components are subjected to exceptionally harsh thermal environments, and the present durability design and analysis capabilities used at original equipment manufacturers (OEMs) are not sufficient to allow for accurate predictions of component life early in the design cycle. Consequently, major Air Force engine programs may be subject to durability problems, including burning, thermomechanical fatigue, and creep of turbine components.

Further to the above, the next generation of military aircraft have a need for lower thrust-specific fuel consumption (TSFC) and higher power-to-weight ratio than current, state-of-the-art turbine systems, and this is consistent with the Versatile Affordable Advanced Turbine Engine (VAATE) program Phase III goals. Increasing turbine durability and/or reducing the durability margin designed into gas turbine components can have a substantial impact in that regard. As such, the Air Force is interested in technologies that have the potential to improve the efficiency of cooled turbine components through development of advanced cooling patterns and internal cooling schemes as well as the rapid verification and validation of those advances during the design cycle. New technologies are desired that enable enhancements in HPT inlet temperature capability while also maintaining and/or enhancing durability and component life. Accordingly, a balanced approach is envisaged that couples the latest advances in physics-based turbine durability design and analysis (that is, conjugate heat transfer) with new concepts for airfoil cooling enhancement as well as an effective means to evaluate those concepts in a relevant environment rapidly and accurately.

The state-of-the-art for turbine durability design, analysis, and verification is provided via the references for this topic. In particular, References 2 through 4 discuss the development, analysis, and testing of a turbine airfoil that is to serve as the baseline for further development in this effort.

PHASE I: Demonstrate the feasibility of innovative technologies to improve HPT component durability and, consequently, TSFC. Develop concepts for improved durability of HPT components with enhanced performance from a given baseline. Conduct heat-transfer, thermomechanical fatigue analyses, and/or experimental verification of candidate technologies and compare performance to that of the baseline system.

PHASE II: Develop, fabricate, and evaluate concepts analyzed in the Phase I effort. This requires experimental verification and validation to demonstrate Technology Readiness Levels on the range from 3 to 5. Assess the effect of the proposed technologies on component durability as compared to the baseline. Further, assess the impact of the proposed HPT component durability technologies on TSFC and power-to-weight ratio.

PHASE III: Anticipated solutions will have a beneficial impact on the design community at OEMs and decrease development time for new systems. This is dual-use technology that would benefit commercial engine systems as well as the development of other heat exchanger systems, for example,in electronic packaging.

REFERENCES:
1. Benson, M., Yapa, S., Elkins, C., and Eaton, J.K., 2012, "Experimental-Based Redesigns for Trailing-Edge Film Cooling of Gas Turbine Blades," ASME Paper No. GT2012-68067.

2. Johnson, J.J., King, P.I., Clark, J.P., Lethander, A.T., Lyons, K.D., Ooten, M.K., Johnson, P.D., and Downs, J., 2010, "Infrared Assessment of Overall Effectiveness of a Modern Turbine Vane Cooling Scheme," AIAA Paper No. 2010-7026.

3. Ni, R.H., Humber, W., Fan, G., Clark, J.P., Anthony, R.J., and Johnson, J.J., 2013, "Comparison of Predictions from Conjugate Heat Transfer Analysis of a Film-Cooled Turbine Vane to Experimental Data," ASME Paper No. GT2013-94716.

4. Ni, R.H., Humber, W., Fan, G., Johnson, P.D., Downs, J., Clark, J.P., and Koch, P.J., 2011, "Conjugate Heat Transfer Analysis of a Film-Cooled Turbine Vane," ASME Paper No. GT2011-45920.

KEYWORDS: component testing, affordable test and evaluation, gas turbine components, cooling technologies, turbine durability, heat exchangers, electronic packaging

AF151-060 TITLE: Common Embedded Vehicle Network Diagnostics Interface Hardware

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a common embedded vehicle network diagnostics interface system on a chip (SOC) for safety-critical vehicle management system functions utilizing advanced protocols to improve reliability, mission availability, and affordability.

DESCRIPTION: New advanced tactical fighter aircraft use a network to pass information between vehicle management system, flight controls, power, landing gear, propulsion, navigation, air data, thermal management, and other utility systems. These systems are safety-critical and are responsible for maintaining control over the vehicle at all times. Because of the importance of military vehicle networks, the network interface standard must be able to send the data quickly, reliably, affordably, with low latency between sensors and effectors, and with immunity to electromagnetic interference (EMI). This is precisely why the world’s most advanced fifth generation fighter aircraft utilizes the SAE AS5643 protocol over an IEEE-1394b compatible data bus for the vehicle management system. The current design includes the ability to self-heal when failures occur, but it can be improved to help maintenance personnel isolate subsystem, wiring, or connector faults. To develop and demonstrate these MIL-1394b improvements, a SOC pure firmware solution on an advanced flash-based field-programmable gate array (FPGA) will be used in place of the existing commercially available industry network hardware.

The purpose of this technology would be to allow the fighter aircraft to improve mission availability rates; this objective will be achieved by minimizing the risk of having a complete total loss of network communication by optimizing the bus re-initialization process after a signal remote node communication failure event, and reduce the amount of troubleshooting time by providing the information needed to detect and isolate the root cause of a vehicle communication network failure. This technology offers size, weight, power, and cost advantages by integrating the external communication interface firmware with the system process and controls algorithms. This technology will offer a more affordable network upgrade path for future tactical fighter vehicle management to incorporate advanced diagnostics, protocol improvements, and speed enhancements. A common embedded vehicle network diagnostics interface SOC will standardize the future of vehicle system networks in other aerospace and defense and commercial markets with a commercially-available, low cost, robust, and DO-254/178B software-compliant SOC for safety-critical vehicle management system control functions.

The current methods used for aerospace vehicle management system control leverages an open system architecture and commercially available IEEE-1394b hardware. This existing technology presents some challenges for the next generation more advanced military vehicles. The new common embedded vehicle network SOC technology offers the ability to provide isolate-and-detect network failures when they occur and prevent the propagation of bus resets from occurring due to normal bus operation. The common embedded vehicle network diagnostics SOC must be compatible with the IEEE-1394b and SAE AS5643 message protocol, and fit on a FPGA in less than 56,000 logic gates, using less than 1.3 MB, consume less than 1 watt of power, support up to eight 3,200 Mb/s SERDES (with a desired goal of 400 Mb/s), and be able to startup within 80 ms. The operating temperature ranges from -60 degrees F to 160 degrees F and atmospheric pressures ranging from 0 feet to 50,000 ft in altitude. The common embedded vehicle network interface SOC interface diagnostics can be approximately 2.2 by 2.3 by 0.345 inches, intrinsically safe, and survive under varying climatic temperature, humidity, shock and vibration loading environments during takeoff, cruise, and landing in accordance with MIL-STD-810F. Prime contractor collaboration is highly encouraged.

PHASE I: Design and demonstrate feasibility of a common embedded MIL-1394b vehicle network interface SOC for use in vehicle systems processing networks. The use of modeling and simulation may be used to demonstrate the feasibility of a common embedded MIL-1394b vehicle network interface SOC technology. Develop initial transition plan and business case.

PHASE II: Complete development of a production representative common embedded MIL-1394b vehicle network interface SOC and conduct a breadboard validation in a hardware laboratory environment. Modeling and simulation capability is highly desirable in order to test core SOC hardware. Develop design documentation artifacts for future certification. A full-scale, simple-to-operate working prototype system is desired for delivery at program completion. Refine transition plan and business case.

PHASE III: A common embedded MIL-1394b vehicle network interface SOC hardware solution should be developed as an end product which can be manufactured, integrated, and maintained for commercial and/or military use.

REFERENCES:
1. J. Narey, "Robust Data Communications for Vehicle Networks," SAE Power Systems and Avionic Systems Conference, September 2012.

2. IEEE 1394b Interface Requirements for Military and Aerospace Vehicle Applications, December 2004.

KEYWORDS: IEEE-1394b, SAE AS5643, field programmable gate array, FPGA, network interface hardware, 1394 Link Layer, 1394 Physical Layer, network transceiver, Society of Aerospace Engineering, SAE

AF151-061 TITLE: Fuel-Property-Independent Injection Technology

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop an injection strategy that is insensitive to liquid fuel properties. The injection strategy should be able to produce similar or better spray properties (for example, SMD, droplet distribution, etc.) for alternative fuels as for JP-8.

DESCRIPTION: Non-fossil fuels, that is, alternative fuels, need to be compatible with the current fleet of military and commercial gas turbine combustion systems. Accommodating these new fuels with existing fuel system technology may cause performance differences in an engine. For example, recent work has illustrated that different candidate drop-in fuels can have slightly different physical properties as well as different chemical composition compared to the baseline JP-8 fuel. At some level, the differences, while seemingly small, may give rise to operability issues, under some conditions. For example, differences in lean blow-off, luminosity, and emissions have been noted. A particularly challenging application for these fuels is their use in combustion systems that may be prone to acoustic oscillations. In these devices, such as augmentors, the fuel is often injected as a liquid jet into a cross flow. As a result, fuel property differences can change jet penetration and droplet dispersion and can give rise to operability differences. Recent work has shown that JP-8 spec fuel derived from different feedstocks can exhibit differences in jet penetration and breakup characteristics. Other work has illustrated the sensitivity of spray behavior (for a fixed fuel) to changes in injector discharge coefficient.

Therefore, it is hypothesized that an interaction in fuel properties and injector internal geometry could be the key to 1) explaining observed differences among the behavior of the fuels and 2) identifying effective strategies to mitigate any differences due to fuel type. If the fuel injection schemes differ for each fuel, then this dictates efforts to design and develop fuel injectors for each fuel, which is cost prohibitive. Thus, it is essential to have fuel-type-tolerant injectors, so that a huge amount of resources can be saved from retrofitting different classes of injectors to accommodate different liquid fuels for combustion systems.

What is desired in this effort is an injector design, or injection strategy, that is inherently insensitive to liquid fuel properties. JP-8 fuel should be used as a baseline to which other alternative fuels can be compared. The alternative fuels used should meet the JP-8 spec but can be derived from alcohol-to-jet (ATJ), hydroprocessed esters and fatty acids (HEFA), and/or the Fischer-Tropsch (FT) process. A mixture of alternative fuels and JP-8 is also acceptable. New ideas should be analyzed and/or tested by comparing the spray properties (SMD, droplet distribution,etc.) of JP-8 to the alternative fuels. For an augmentor application, test conditions can range from 100 to 300 psi for the fuel spray entering into a cross flow of 0.5 to 3.0 atm. The temperature range of the cross flow is from 100 degrees F to 1700 degrees F, although testing at high temperatures is not necessary for a Phase I effort.

Consideration for retrofit applications as well as incorporation into future concepts should be given for any idea proposed.

This is a DoD-wide issue as non-fossil-derived fuels become more common.

Partnership and/or teaming with engine OEMs are highly recommended.

PHASE I: Determine feasibility of one or more injection concepts for mitigating sensitivity to fuel properties using analysis and experimentation in a laboratory environment. A measurement strategy for assessing the property-independent behavior of the injection system should be developed. Develop initial transition plan and business case analysis.

PHASE II: Promising concepts from Phase I should be integrated into appropriate sector scale experiments and the ability of the concept to mitigate negative impact on combustion performance demonstrated. Attention should be given to isolating individual fuel property effects on combustion performance, which requires consideration of the physical and chemical time scales. Integrating the concept under thermal stability and real estate constraints should be proven. Refine business case and transition plan.

PHASE III: The developed technology will provide a tool for designing fuel systems for combustors and augmentors that enable alternative fuels to be true drop-in replacements. It would also be useful in combustors for commercial aircraft.

REFERENCES:
1. Pandey, R.K., Rehman, A., and Sarviya, R.M., (2012). "Impact of alternative fuel properties on fuel spray behavior and atomization," Renewable and Sustainable Energy Reviews, Vol.16(3), pp. 1762-1778.

2. Gu, X., Basu, S., and Kumar, R., (2011). "Dispersion and vaporization of biofuels and conventional fuels in a crossflow premixer," International J. of Heat and Mass Transfer, Vol. 55 (1), pp. 336-346.

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4. Thomas, A.E., et al., "Heating and efficiency comparison of a Fischer-Tropsch (FT) fuel, JP-8+100, and blends in a three-cup combustor sector," ASME 2012-7008, Proceedings of ASME Turbo Expo 2013, Copenhagen, Denmark, June 11-15, 2012.

KEYWORDS: JP-8, jet fuel, alternative fuel, fuel injection, liquid fuel, fuel properties

AF151-062 TITLE: Low-Weight, High-Temperature Passive Damping System for Afterburners

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a damping strategy to mitigate combustion instabilities over a wide range of afterburner operating conditions. The target frequencies are from 100 Hz to 1000Hz with an 80 percent reduction in peak-to-peak pressure oscillations.

DESCRIPTION: Perforated liners act as acoustic narrow band filters, damping pressure fluctuations and in turn saving hardware from high-cycle fatigue. Current technology uses perforated liners to damp high frequency instabilities. However, in general acoustic liners have a limited damping capability below 1000 Hz and traditional Helmholtz-type resonators for low frequencies result in significant issues with weight (tens of pounds), size (characteristic lengths of a foot or more), and packaging. Empirical correlations are typically used for designing acoustic liners that are based on parameters such as effective area of the perforated holes, flow length scales and engine cycle temperatures and pressures. These designs are then tested in rigs and engines to show their damping effectiveness. Oftentimes the design needs to be modified after the engine test since typical engine conditions are not easily attained in a rig test. In the absence of a detailed design database and procedure, current design methodologies are questionable, especially for next generation systems, for which boundary conditions such as temperature, vitiation level, operating pressure, velocity/Mach number, and turbulence levels are expected to be more severe. The local flow conditions in today's augmentors greatly deviate from the global parameters used to design them. Because of this, improved concepts that capture the local physical phenomena and are able to withstand the increased thermal operating conditions are required.

Typical methods used to eliminate screech and low frequency instabilities generally employ an trial and error method, which can be cost prohibitive, especially when applied to fielded systems. Because of this, strategies for low-frequency acoustic absorption without excessive size and weight penalty are required.

This SBIR topic is not limited to only new devices. An analytical strategy or acoustic model that models the acoustic behavior of the whole exhaust system, from the exit of the low-pressure turbine to the nozzle exit--that may inspire new damping ideas--is also sought.

The frequency range of interest is from 100 Hz to 1000 Hz. Consideration should be given to eventual transition into a gas turbine engine where metal temperatures can exceded 1000 degrees F and the gas temperatures can be even hotter. Material properties, size, weight and packaging will be very important in a successfully developed device. The objective is an 80 percent reduction in peak-to-peak pressure oscillation for the frequency range of interest.

A strong collaboration with the OEMs is highly recommended from the inception of this program.

In order to successfully perform the work described in this topic area, offerors may request to utilize unique facilities/equipment in the possession of the U.S. Government located at Wright Patterson Air Force Base, Ohio, during the Phase II effort. Accordingly, the following items of base support may be provided, on a no-charge-for-use basis, to the successful offeror, subject to availability. The facilities/equipment include an atmospheric pressure, single-flameholder rig. The rig operates on propane fuel and has a combustion instability around 120 Hz.

PHASE I: Show the feasibility for a damping strategy for frequencies as low as 100Hz, through either analytical or experimental analyses. Develop a test strategy for evaluating the ideas and identifying the key performance parameters necessary to document any improvement over current devices, such as a perforated acoustic liner. Develop an initial transtion and business plan.

PHASE II: Extend the device to a prototype to include testing at typical afterburner conditions at various design points. Demonstrate an improvement of at least 75 percent damping effectiveness over the frequency range of interest. Refine transition plan and business case.

PHASE III: The developed technology would enable the design of augmentors with greater stability and able to operate over a larger portion of the flight envelope. It can also reduce maintenance costs by increasing time on wing for exhaust system hardware.

REFERENCES:
1. Kinsler, L.E., Frey, A.R., Coppens, A.B., and Sanders, J.V., "Fundamentals of Acoustics," John Wiley and Sons, 4th ed., pp. 284-286, 2000.

2. Eldredge, J.D. and Dowling A.P., "The absorption of axial acoustic waves by a perforated liner with bias flow," J. of Fluid Mechanics, Vol. 485, pp. 307-335, 2003.

3. Gullaud, E., et al., "Damping effect of perforated plates on the acoustics of annular combustors," AIAA 2009-3260, 15th AIAA/CEAS Aero-acoustics Conference, 11-13 May 2009, Miami, FL.

4. Heuwinkel, C., et al., "Establishment of High Quality database for the modeling of perforated liners," GT-2010-22329, Proceedings of ASME turbo expo 2010, Power for Land, Sea and Air, June 14-18, 2010, Glasgow, U.K.

KEYWORDS: afterburner, augmentor, damping, combustion instability, screech, acoustic radiator, high temperature, vitiated freestream, acoustic loads, pressure fluctuation, structural failure

AF151-063 TITLE: High-Speed, Two-Dimensional Sensor Suite for Fuel-Air Ratio and Heat-Release Rate for Combustor/Augmentor Stability

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop, apply, and package innovative, high-speed, noninvasive diagnostic technologies at high spatial and temporal resolutions for two-dimensional measurements of local wake fuel-air ratio and heat release rates in combustor/augmentor test rigs.

DESCRIPTION: Combustion instability is a challenging issue generally encountered in gas turbine combustors and augmentors. Combustion instability typically arises because of complex physical coupling between the unsteady heat release and the resonant acoustic modes inside the engine. This thermoacoustic instability can produce large pressure fluctuations that can lead to reduced engine performance and severe structural damage. In modern gas-turbine augmentors, instability or screech/rumble modes evolve both spatially and temporally and typically occur in frequency ranges from hundreds to thousands of hertz. Since local heat–release rates vary in a combustion process, various modes and degrees of thermoacoustic instabilities will be exhibited. Moreover, because of the complex physical and chemical reactions involved in thermoacoustic instabilities, these instabilities are difficult to predict. Typically, the measured flame-transfer function between heat release fluctuation and equivalence ratio (i.e., fuel-air ratio) fluctuation is required as a direct input for a combustion instability model. Noninvasive laser-based measurement technologies capable of measuring heat-release rate (HRR) and fuel-air ratio (F/A) at multiple spatial points and at a data acquisition rate of 10 kHz or greater is required to address the combustion instability issues in gas–turbine augmentors. In addition to these primary performance parameters (i.e., HRR, F/A), the secondary performance parameters of interest are velocity, temperature and concentration distribution of key combustion species such as OH, CH, CO and CO2. These parameters can provide information on local flame-front phenomena and interactions between turbulent flows and chemical reactions for screech mitigation technology development.

There exist short- and long-term needs to develop practical sensing tools that will enable researchers and manufacturers to capture local variations of heat release, fuel-air ratio, and other parameters of interest (i.e., velocity, temperature, species concentrations) as a function of time. This knowledge will help track the dominant mechanisms that lead to and help sustain combustion instabilities, impacting designs of new technology. Fundamental laboratory research and development efforts are required to develop and demonstrate laser-based sensor systems for two-dimensional (2D), high-speed measurements of HRR and quantitative F/A in augmentor systems.

It is highly desirable that the developed sensor systems are designed with an emphasis on robustness for challenging combustion rig environments and are appropriately packaged for integration into probe housings capable of measurements in combustion hot zones on the order of 2500K and with an overall diameter approximately 12 mm or less. The current state-of-the-art diagnostic approaches that provide spatially and temporally resolved local flowfield measurements involve free-standing optics, packaged in considerably larger diameters, or involve approaches that are not feasible for probe integration into realistic test rigs or engine test stands at Arnold Engineering Development Complex, Tenn., or OEMs. Exploring fiber-based measurements of HRR and F/A with the aim of transitioning these sensor systems to realistic gas-turbine engine test facilities is highly encouraged. Emphasis should be placed on robust and compact packaging, integrating with existing cooled-probe bodies.

In order to successfully perform the work described in this topic area, offerors may request to utilize unique facilities/equipment in the possession of the U.S. Government located at Wright-Patterson Air Force Base (WPAFB), Ohio, during the Phase II effort. Accordingly, the following items of base support may be provided, on a no-charge-for-use basis, to the successful offeror, subject to availability: The facilities/equipment include specific

AFRL water-cooled probe housings and access to the Atmospheric Pressure Combustion Research Facility, High Pressure Combustion Research Facility, and the Combustion and Laser Diagnostics Research Complex, with their respecitive equipment inventory.

Teaming with prime contractors is highly encouraged.

PHASE I: Perform research to demonstrate the feasibility and packaging of advanced diagnostic sensing approaches for high-speed (=10 kHz), 2D HRR, and F/A in laboratory scale turbulent flames for various hydrocarbon fuels.

PHASE II: Fully develop, package, and deliver an advanced diagnostic sensor system capable for local flowfield measurements in liquid– and gas–fueled combustor/augmentors test rigs. Ideal demonstration of sensor capabilities is in a realistic flowfield found in either atmospheric/high-pressure combustion test rigs or augmentor test rigs located at WPAFB. Base support may be granted for access to additional equipment as well as other facilities. Refine technology transition plan and business case analysis.

PHASE III: Measurement technologies demonstrated herein can be used in development and procurement programs for the collection of high-quality data for validation of design, performance, and robustness. Packing must be robust and compact.

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1. B. O. Ayoola, R. Balachandran, J. H. Frank, E. Mastorakos, and C. F. Kaminski, "Spatially resolved heat rate measurements in turbulent premixed flames," Combust. Flame 144, 1 (2006).

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KEYWORDS: laser diagnostics, combustion instability, high-speed measurements, augmentor, heat release rate, fuel-air ratio

AF151-065 TITLE: Reduced-Order Model for the Prediction of Supersonic Aircraft Jet Noise

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: To develop an analytical tool that assesses jet noise and engine performance from current and future supersonic two- and three-stream engines.

DESCRIPTION: The noise from military aircraft continues to be an environmental concern which increasingly constrains DoD flight operations. Noise regulations proposed by the International Civil Aviation Organization (ICAO) over the last two decades have continued to require source reduction of noise emitted from commercial aircraft. Noise from military tactical aircraft continues to grow as the need for engines with higher thrust and lower fuel consumption drives turbine engine technology development. High noise exposure from aircraft operations is effectively constrained by compatible land uses in residential communities around military bases. Aircraft engine noise also has a more acute impact of potential hearing loss on airport ground crews, and military aircraft carrier launch/recovery crews.

Research is ongoing in the area of supersonic jet noise assessment and reduction. Several methods have been developed since the 1980 to identify specific jet noise sources in supersonic jets. As a result, noise from round supersonic turbo fan engines is becoming well understood. Novel three-stream architectures are currently under development in the DoD. In these systems, a second fan stream, or third steam, is used to optimize the engine over many cycle points. Three-stream engines have the potential for up to 25 percent fuel savings. The independent third stream nozzle creates shock and turbulence interactions that are very different from round supersonic jets. Future nozzles may also be rectangular instead of round. Finally, the aircraft will have an integral aft deck with which the supersonic jet and third stream will interact. Noise sources from these types of nozzles with these features are not well understood or well modeled.

Currently available noise models predict noise from subsonic and round supersonic two stream nozzles well. These models, however, do not accurately predict noise from supersonic three-stream jets, from other than round configurations with three-streams, and from configurations with integral aft decks. These models also do not simultaneously predict engine cycle performance. As three-steam engine systems are new, the trade space between the various exhaust system parameters, jet noise, and system performance is also not well understood.

Desired is a tool for assessing the jet noise spectrum from current, two-stream, and future two- and three-stream gas turbine engines for supersonic aircraft. The tool must interface with gas turbine engine cycle assessment tools such as Numerical Propulsion System Simulation (NPSS). The Air Force Research Laboratory has a government-owned two-/three-stream cycle tool called the GATE model with an NPSS interface. The GATE model will be made available as necessary. The noise assessment tool should be capable of analyzing systems engineering alternatives and evaluate trades between nozzle geometry, jet noise and engine performance. The tool should be reduced order in nature but capture the physics of two- and three-stream noise sources. The tool should be well validated with experimental or computational data. The tool must be able to make a noise and engine performance assessment of an engine configuration under two hours. The tool should be able to run on a standard personal computer/Apple Mac. Teaming or partnership with original equipment manufacturers (OEMs) is highly encouraged.

PHASE I: Perform proof-of-concept demo of a reduced-order tool for supersonic noise prediction. Develop strategies to fill the gaps in noise data from the current database from experiments and computations. Assess available cycle assessment tools and develop strategy for integrating the noise and cycle assessment tools. Develop technology transition plan and initial business case analysis.

PHASE II: Develop an integrated jet noise and performance prediction tool. Conduct experiments and/or simulations to fill gaps in validation data for supersonic jets and advanced technologies. Validate the tool over a range of jet nozzle pressure ratios and nozzle configurations. Demonstrate accurate prediction of jet noise and engine performance. Refine transition plan and business case analysis.

PHASE III: The developed tool will provide a predictive capability to assess performance and noise impacts from new nozzle configurations and noise suppression technologies for future supersonic fighters and attack aircraft.

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1. Hendricks, E.S., and Seidel, J.A., 2012, "A Multidisciplinary Approach to Mixer-Ejector Analysis and Design," AIAA2012-4224.

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KEYWORDS: jet noise, supersonic jet, tactical aircraft, three stream gas turbine engine

AF151-066 TITLE: Monopropellant Thrusters for Cubesats

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Enable military utility of cubesats by providing responsive propulsive capability.

DESCRIPTION: Cubesats are an emerging class of responsive spacecraft. Cubesats are small, yet capable platforms, with mass between 4 kg (3U) to 10 kg (6U) and constrained volumes of 3,000 cm3 to 6,000 cm3. These small spacecraft are demonstrating tremendous potential for low-cost access to space. However, militarily useful missions require spacecraft maneuverability. Presently, only cold gas propulsion with low velocity change (delta V) capability (< 10 m/s) has been demonstrated onboard cubesat spacecraft. Developing cubesats with substantial propulsive capability will enable useful, low-cost DoD access to space. Due to cost constraints, traditional cubesat component developers (small businesses and university research programs) are not able to independently develop propulsion modules to acceptable levels of maturity.

Due to the low amounts of electrical power available to cubesats, monopropellant chemical propulsion may provide a simplest method by which substantial propulsive capability (100-200 m/s) can be integrated onto a spacecraft. Very small chemical systems may have lower specific impulses than a number of electric propulsion concepts, but monopropellant thrusters are not limited by low electrical power levels and can produce much higher thrust levels for rapid maneuvers. The technical challenges of this program lie in the ability to both maximize propellant throughput and performance in a power limited, low volume, and low mass architecture.

Propulsion systems of interest must overcome substantial architectural limitations, these include packaging within 200-500 cm3 volume, consume less than 15 W of average power, and a total lifetime system impulse greater than 500 Ns over a mission lifetime of 12 months. Complete cubesat propulsion systems are the goal of this program. This requires definition of a system architecture followed by the development of all critical subsystems. The critical sub-systems include the thruster, propellant storage/management, power conditioning, and digital control. Thrust technologies from plasma propulsion to electrosprays will be considered, but only well defined systems with clear architectures that lead to transitionable technologies with capabilities in excess of that defined previously will be considered.

PHASE I: Perform proof-of-concept analysis and experiments that demonstrate the feasibility of the proposed propulsion cubesat system concept. Emphasis will be on system architecture in addition to demonstration of thruster.

PHASE II: Development of system with verification via experimental measurements and analysis that demonstrates the proposed cubesat propulsion system will meet required performance within realistic cubesat constraints.

PHASE III: DoD applications are for existing cubesats and other small platforms. Commercial applications include the use of distributed nanosatellite constellations for communications and environmental sensing.

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2. C. Buddy, T. Svitek, “Monopropellant Micro Propulsion System for CubeSats,” 23rd Annual AIAA/USU Conference on Small Satellites, Aug 10-13, 2009, Logan, UT.

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KEYWORDS: cubesat, micro-chemical propulsion, monopropellant, Pico Satellite Propulsion

AF151-067 TITLE: Advanced Electrochemical Power Sources and Lithium-Ion Batteries for Space-Launch Vehicles

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: The purpose of this effort is to develop lightweight electrochemical power sources for space launch vehicle upper stages and low cost, safe, and lightweight flight termination system batteries for space launch vehicle first stages.

DESCRIPTION: Due to the increasing obsolescence of silver-zinc (Ag-Zn) battery technology and the longer mission durations needed for upper stage disposal, there is a need for two different types of batteries (possibly lithium-ion) and a new power generation system for the upper stage. The first battery (Bat 1) will be required to generate a voltage of 28.0 to 32.0 volts (V) and have a minimum capacity of 1.5 amp-hours (A-h). The Bat 1 must weigh less than 7 lb with a desired weight of 5.6 lb and be able to produce a maximum current of 20 amps (A). The Bat 1 dimensions should not exceed a length of 8.75 inches, a width of 3.45 inches, and a height of 3.65 inches. Environmental temperatures are expected to be in the range of 60 to 120 degrees F with operational mission duration of 30 minutes (min). The second battery (Bat 2) is similar to the first except that the mission duration is 8 hours (hrs) or greater, the maximum current is 250 A, weigh less than 20 lb, with a desired weight of 16 lb. The Bat 2 dimensions should not exceed a length of 11.5 inches, a width of 5.25 inches, and a height of 6.7 inches. The power system (PS) for the upper stage (battery or fuel cell) will be required to generate a voltage of 27.0 to 32.0 V and have a minimum capacity of 150 A-h. The PS weight must be less than 92 lb. with a desired weight of 74 lb. and be able to produce a maximum current of 250 A. The PS dimensions should consist of length 12.85 inches, width of 11.7 inches, and a height of 8.55 inches. Environmental temperature ranges are expected to be in the range from 30 to 130 degrees F. All three power units must withstand random vibration environments up to 65 grms in all three axes, three shocks of 1,300 g’s sustained from 2,000 to 10,000Hz in the positive and negative directions of all three axes. The primary purpose of Bat 1 and Bat 2 is for the first stage flight termination system of the space launch vehicle requiring robust, safe, and low-cost batteries. To be competitive with other types of power sources, the space launch vehicle upper stage PS will require very high energy densities for anticipated mission durations exceeding 12 h. as well as being robust, safe, and low-cost.

During Phase II, the offeror will produce three different prototype power sources (battery and/or fuel cell) for the Air Force space launch vehicle application. The offeror will also compare the performance to the baseline batteries. Prototypes should be delivered to the AF for additional testing and evaluation. At the end of the contract, the offeror should also demonstrate the prototypes at Wright-Patterson AFB, Ohio, to outbrief technology advancements.

PHASE I: Design innovative, safe, rechargeable space launch vehicle batteries for the first stage and the upper stage. The batteries will have equivalent/better energy/power density capability relative to currently used Ag-Zn battery technology. Present experimental and other data to demonstrate feasibility of proposed solution. Develop initial transition plan.

PHASE II: Build and demonstrate prototype, safe power sources (battery and/or fuel cell) using the developed configurations determined during Phase I for Air Force space launch vehicles. Provide cost projection data substantiating the design, performance, operational range, acquisition, and life cycle cost. Refine transition plan and business case analysis.

PHASE III: Military applications include space launch vehicles, missiles, emergency and pulse power, electric tracked vehicles, unmanned systems, hybrid military vehicles, and unmanned underwater vehicles (UUVs). Commercial applications include space launch vehicles and hybrid and electric vehicles.

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1. Kim, G.H., Smith, K., Ireland, J., and Pesaran, A., "Fail-safe design for large capacity lithium-ion battery systems," J. Power Sources, Vol. 210 (2012) pp. 243-253.

2. Jacoby, M., "Safer Lithium-Ion Batteries," Chemical & Engineering News, Vol. 91 (2013) pp. 33-37.

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KEYWORDS: lithium-ion, batteries, fuel cells, safety, rechargeable, launch vehicle, flight termination system, upper stage

AF151-068 TITLE: <u>Solar Electric Propulsion for Agile Space Capabilities</u>

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop agile, high-thrust solar electric propulsion technologies that enable/enhance mission capabilities and improve responsiveness for national security space assets.

DESCRIPTION: Pervasive electric propulsion (EP) technologies greatly enhance in-space maneuverability and spacecraft payload capacity for many DoD missions, such as transfer to Geostationary Earth Orbit (GEO), when compared to liquid chemical propulsion [Ref 1]. However, state-of-the-art electric EP systems do not provide sufficient thrust to perform some time critical maneuvers with available on-board power. For superior payload capability and increased risk mitigation redundancy for DoD space assets, a high efficiency EP technology compatible with chemical propellants could be paired with a chemical thruster to produce an agile and efficient multi-mode propulsion (MMP) system. An agile MMP system with shared propellant and tanks reduces system complexity and increases risk mitigation redundancy by enabling flexible and optimal utilization of propellant between the EP and chemical thruster system for in-space maneuvers, including orbit transfer, repositioning, station-keeping, attitude control, and disposal. In addition, the agile and flexible nature of MMP enables dynamic orbit transfers, rapid response, and sustainable repositioning.

Realizing these advantages requires innovative solar electric propulsion technologies with high efficiency and high thrust when operated with lightweight, molecular propellants used in chemical propulsion, such as hydrazine or advanced “green” energetic monopropellant formulations. Examples of electric thruster concepts that have demonstrated operation with chemical propellants include hydrazine arcjets, magnetoplasmadynamic (MPD) thrusters, pulsed inductive thruster (PIT) concepts, and field-reversed configuration (FRC) propulsion [Ref 2-6]. To date, these EP technologies have not met the performance and lifetime requirements needed for agile in-space capabilities.

This solicitation seeks research on electric thruster technologies capable of achieving specific impulse from 1500-2500 seconds with total thruster efficiency greater than 60 percent using a chemical propulsion propellant. Proposal solutions may be either ideas for improving existing thruster technology or the development of new concepts. Specific power of the thruster and power processing electronics should be less than 3 kg/kW. A representative power level for this technology is 3-10 kW per thruster, though demonstrations may be conducted at different power levels or with simulated propellant to accommodate cost-effective research activities. The full propulsion system (thruster, power processing unit & propellant feed) should define a clear path for transition to national security space applications in the proposal.

The thruster technology should be capable of supporting a 15-year mission in GEO or Medium Earth Orbit (MEO) and five years in Low Earth Orbit (LEO) after ground storage of five years.

PHASE I: Perform proof-of-concept analysis and experiments that demonstrate the feasibility of the high performance electric propulsion concept for an agile multi-mode propulsion system.

PHASE II: Measure performance and plume characteristics of breadboard hardware to demonstrate program goals for the high performance electric propulsion concept for a MMP system. Breadboard hardware will be evaluated on thrust stands at Air Force Research Laboratory, and achieve Technology Readiness Level 5 at the end of Phase II activities. Deliverables include breadboard hardware, preliminary cost analyses, and full performance analysis with comparison to state-of-the-art EP.

PHASE III: The high-performance electric thruster will enable agile MMP systems with improved payload capability, reduced system complexity, and increased risk mitigation redundancy for national security space assets. This technology is suitable space tug or communications satellite orbit transfer operations.

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1. Brown, D. L., Beal, B E., Haas, J. M., “Air Force Research Laboratory High Power Electric Propulsion Technology Development,” IEEEAC Paper #1549, Presented at the IEEE Aerospace Conference, Big Sky, MT, March 3-7, 2009.

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KEYWORDS: electric propulsion, multi-mode propulsion, High Delta-V, agile, flexible, energetic monopropellant

AF151-069 TITLE: Noncontacting Full-Field Real-Time Strain Measurement System for Air Platforms in Combined Extreme Environments

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop integrated noncontacting full-field real-time strain measurement system to interrogate full-field strains in combined extreme thermal (>1800 degrees F) & acoustic (about 165dB, 0 to 1000Hz) loading conditions for use in hypersonic vehicles.

DESCRIPTION: The U.S. Air Force has a critical need for non-contacting sensor technologies applicable to structural response strain measurements in extreme and harsh environments. Game-changing reusable high-speed air platforms critical to the global reach and superiority of tomorrow's Air Force will experience long-duration, time-varying, non-periodic, combined and intense, thermo-mechanical-acoustic loads over significant portions of their structure. Designing and fielding these platforms requires the capability to experimentally verify and validate structural response, life prediction and durability assessment models and methods under these complex and challenging loading environments.

Lack of the necessary knowledge has resulted in significant repair and replacement costs for exhaust nozzles and exhaust-washed structures of existing Air Force platforms operating under combined, thermo-acoustic-mechanical loads, even when these loads are far more benign than those associated with hypersonic flight. A full-field, real-time, strain measurement system would fill a critical gap in the capabilities needed for efficient and effective life testing of these complex structural components and would enable verification and validation of computational methods and models used for structural analysis, design and reliability assessment.

While some noncontact methods, such as full-field digital image correlation (DIC) can go beyond point-wise strain measurements by providing the strain field over a reasonable-sized region of the structure under test, these methods are typically only able to provide detailed strain data after the test is over, due to the large volume of data that must be processed from the images that are used to extract the strain fields. The suitability of these non-contact methods to deliver real-time, full-field, strain measurement, which can be used for feedback control during the test, is severely limited. Moreover, the efficacy of these methods decays at high temperatures due to the de-correlation effects related to radiant light emanating from the sample at the upper end of the temperature regime, which is where the information is often most-desired.

The goal of this effort would be to develop a non-contacting, full-field, strain measurement system that can provide real-time or quasi-real-time strain data for structures at temperatures in excess of 1,800 degrees F, simultaneously subjected to high levels of broadband acoustic loading (165 dB, 0 to 1000Hz).

To successfully perform the work described in this topic area, offerors may request to use unique facilities/equipment in the possession of the U.S. Government located onsite at Wright-Patterson Air Force Base, Ohio, during the Phase II effort. Accordingly, the following items of base support may be provided, on a no-charge-for-use basis, to the successful offeror, subject to availability: The facilities/equipment include the FASTCAM SA5 ultra high-speed video system (1 megapixel at 7,500 fps) and a 20,000 lbf electro-dynamic shaker with liquid cooled grips for high temperature testing.

PHASE I: 1) Demonstrate & document a technique for accelerating the delivery of noncontacting full-field 2-D strain measurements; 2) develop a sound technical approach to overcome shortfalls of the system for use at elevated temperatures (greater than 1,800 degrees F); and 3) develop experiments and demonstrate this technology for low image resolutions, showing the scale-up expected at higher resolutions.

PHASE II: Develop, demonstrate, and deliver a prototype accelerated information delivery noncontacting, 3-D, full-field strain system that can operate within the combined thermal static/dynamic loading conditions characteristic of a hypersonic flight environment. The prototype must be suitable for use on component-level tests on high-temperature metallic and nonmetallic aerospace structures.

PHASE III: Military Application: This technology would be used in the testing of current and future hypersonic vehicle components and structural sub-assemblies. Commercial Application: This technology is applicable to the validation of manned and unmanned commercial space vehicles and engine components.

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KEYWORDS: high-temperature strain measurement, combined extreme environment strain measurement, full-field strain measurement, real-time strain measurement

AF151-070 TITLE: Modular Motor Drive with Programming and Configuration Tools for the Development of Small Aircraft Electric Power and Propulsion Systems

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Enable the rapid development of advanced UAV electric propulsion concepts by delivering a modular 3-phase motor/generator control solution that provides a user-programmable processor module with compatible and interchangeable power stage elements.

DESCRIPTION: The FY2013-2038 Unmanned Systems Integrated Roadmap designates efficient power generation, noise reduction, and increased aircraft power as near-term propulsion goals for unmanned systems and sites detectability as the first of five key survivability elements. Requirements for more electric on-board power to enable the utilization of advanced electronics payloads and advantages in quiet propulsion has driven extensive DoD investment in power-dense permanent magnet motor and generator applied research and development for unmanned systems.

The focus of this topic is to fill a commercial void in the area of suitably flexible brushless and synchronous permanent-magnet motor/generator controllers appropriate for electric unmanned aerial vehicle (UAV) flight applications. In-house development of custom motor control electronics is outside of the expertise of typical UAV developers. As a result, small businesses have struggled implementing commercial-off-the-shelf (COTS) solutions due to incompatibility with desired control requirements, existing industrial automation drives, and high-performance aircraft electric motors.

UAV power and propulsion engineers require a modular electric motor control solution with interfacing and control features not available on commercial RC hobby controllers as well as packaging more suitable for flight applications than industrial automation controllers. Often, advanced propulsion applications require user-developed inner loop control logic, which also is not a commercially available option.

A programmable processor module and plug-and-play integration with selectable power stage modules would allow UAV developers to eliminate expensive motor control development without having to compromise aircraft operability using an unsuitable commercially available motor controller. This will enable user-configured control logic specific to the aircraft's propulsion technology, advanced control through adequate sensor and processor interfacing, and electronics package weight, volume, and cooling optimization.

The Air Force is looking for:
- Innovative modularity – power scalability and interface options allowing users to optimize electronics weight and volume while meeting mission requirements.
- Default tunable motor control logic - software configuration tools that allow users without expertise with motor control to implement velocity and torque control.
- Unrestricted access to modify current and voltage loop logic - software development tools that permit controls experts without embedded hardware expertise to implement custom processor intensive control loop algorithms. This shall include configuration and access to available input/output (I/O) and gate drive parameters.

Offerors are required to propose suitably flexible control and power modules that provide the following commercial and military applicable specifications:
- Control for Permanent Magnet Brushless DC and Synchronous Machines
- Modularity scalable over a range of 0.5-30[kW].
- Minimal footprint thermal interface to user selectable/provided air or water cooling.
- User selectable position feedback to include resolvers, encoders, and sensorless.
- Six isolated PWM outputs for power module gate drives.
- One isolated PWM output for a breaking resistor (recommended).
- Switching frequencies in excess of 20kHz; capable of 1kHz+ electrical frequency.
- Processor module shall be capable of commanding future power modules that have switching frequencies in excess of 120kHz.
- Suitable electronics for motor inductance as low as 2uH.
- Processor module provides SPI, I2C, and JTAG as a minimum set of hardware interfacing is recommended.
- A third module is recommended for allowing for minimized complexity and weight of the processor module which is to provide communication interfaces such as the encoder/resolver interface and additionally CAN, RS485, and optionally USB protocols.
- ADC interfaces (0 to 5 V) and Discrete I/O with overvoltage and transient protection.
- Common programming interface such as C.
- Optimized size and weight. Proposals will be evaluated on size and weight metrics relative to expected durability and operability.
- It is recommended that proposals focus on current technology's usability & integration and refrain from proposing discrete technology advancements in materials or performance.
- It is highly recommended that offerors provide a commercialization plan that includes partnership with an interested UAV manufacturer.

PHASE I: Develop and demo a modular motor control solution with a single processor module, recommended I/O module, and interchangeable stage power modules. The Phase I deliverable shall include a feasibility demonstration that satisfies basic requirements of function and flexibility of the concept. Offer shall include a plan to transition to a flightworthy hardware design for a possible Phase II effort.

PHASE II: Phase II will produce a flight weight prototype with a threshold requirement of testing in a relevant environment and an objective requirement of flight testing. A partnership with an interested UAV developer is highly recommended. Two different power stage modules will be tested demonstrating scalability.

PHASE III: Military applications include intelligence, surveillance, and reconnaissance (ISR), target tracking and acquisition. Commercial applications include border patrol and search and rescue for emergency responders.

REFERENCES:
1. FY2013-2038 Unmanned Systems Integrated Roadmap.

2. Department of Defense, Small Business Innovation Research Topic AF103-209, "Internal Combustion (IC) Engine/Electric Hybrid Power/Propulsion System for Small Unmanned Aerial Vehicles (UAVs)."

3. (Reference was removed on 1/28/2015 since it is not available for release to the public at this time.)

KEYWORDS: power, electrical power, UAV, electric propulsion, motor control, motor drive, inverter, electronics

AF151-071 TITLE: Compact High Channel Count, High Frequency, Rotating Data Acquisition and Transmission

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop, demonstrate, and deliver a compact, wide bandwidth, rotating data acquisition and signal conditioning device scalable to high-channel count to fit inside rotating machinery.

DESCRIPTION: Reduced aircraft engine maintenance costs and improved designs for future aerospace systems require accurate knowledge and understanding of complex rotating component boundary conditions. Advanced numerical simulations now provide high-fidelity predictions that must be validated in real-world component testing or operation with an escalating number of rotating sensors. Current analog slip-ring solutions for high channel count (greater than 300 wires) are limited by excessive wiring and noise pickup across long analog signal lengths and connectors. Available compact shaft embedded digitization and transmission devices (less than 3.5-inch inner diameter by 3-inch length) currently provide either high bandwidth capability (greater than 100 kHz) with relatively low-channel count (less than 80), or high channel count (greater than 80) at relatively low bandwidth (less than 1 kHz). Advanced system testing requires the need for both high-channel count, high bandwidth data collection in a compact package that can reduce wiring and noise.

This program aims to develop scalable high bandwidth (up to 150 kHz) rotating electronics to condition and digitize (greater than 300 kSamples/s) low level analog signals on rotating hardware and output a high quality digital data stream that eliminates or reduces current wire count per channel by a factor of 50 or more. This topic advances technology beyond state of the art by targeting these requirements for 80 or more simultaneously sampled channels in a very compact design (3.5-inch inner diameter by 3-inch length) to be embedded inside a rotor hub with channel noise not to exceed +/- 0.5 percent FS. To accommodate added sensors and alternate signal conditioning, the electronics should be modular and scalable, that is, multiple boards may be stacked to allow over 100+ channels with integrated signal conditioning for either high frequency (150 kHz) constant current RTD devices, constant voltage pressure transducers (150 kHz), or miniature thermocouples (up to 20 kHz). Data at max sampling rate needs to be acquired for at least 2.5 s and may be stored in memory on-shaft for post-acquisition download either via digital transmission through a smaller slip ring or wireless telemetry. All data channels must be simultaneously sampled at 16-bit minimum (24 bit preferred). Remote software should allow limited programmable settings such as channel gain (1 to 1000) and anti-alias cutoff frequency (25-150 kHz). Channel expansion beyond 80 channels may be allowed by extending the 3 inch axial length with an expandable modular design. Following initial prototype testing, the device will be demonstrated with fully-instrumented hardware at the Air Force Research Lab (AFRL) Turbine Research Facility at Wright-Patterson Air Force Base (WPAFB), Ohio. The new capability may then serve multiple dual-use military and commercial applications (i.e., turbomachinery, such as fans, compressors, or turbines; landing gear; rotary aircraft; and various land-based vehicles and power systems).

To successfully perform the work described in this topic area, offerors may request to utilize unique facilities/equipment in the possession of the U.S. Government located onsite at WPAFB. Accordingly, the following items of base support may be provided, on a no-charge-for-use basis, to the successful offeror, subject to availability: The facilities/equipment include the AFRL Turbine Research Facility at WPAFB and certain instrumented rotating turbine hardware therein.

PHASE I: Complete prototype design and feasibility assessment. Plan a simplified Rotating Bench-Top Test Experiment up to 25,000 RPM. If possible, demonstrate functionality, software control and evaluate signal-to-noise ratio, bandwidth, data transmission, and remote software communication of a single channel prototype.

PHASE II: Optimize the prototype design based on analysis of Phase I results and test full channel count version in rotating bench-top tests. Build an improved version for demonstration in a full scale, highly instrumented rotating rig test. Full scale instrumented hardware, test integration, and performance assessment will be performed with the AFRL Turbine Research Facility at WPAFB.

PHASE III: Transition the new capability to multiple dual-use military and commercial applications both within and outside legacy and future Aerospace Systems such as turbomachinery (fans, compressors, or turbines), landing gear, rotary aircraft, various land-based vehicles and power systems.

REFERENCES:
1. Zeisberger, A., Matziol, L., and Deubert, F., 2002, "Modern Telemetry Systems and Rotating Instrumentation," ASME International Gas Turbine Institute Turbo Expo, ASME Paper No. GT2002-30048.

2. Anthony, R.J., and Clark, J. P., 2013, "A Review of the AFRL Turbine Research Facility," ASME International Gas Turbine Institute Turbo Expo, ASME Paper No. GT2013-94741 (uploaded in SITIS 12/19/14)

3. Anthony, R. J., Clark, J. P., Finnegan, J. M., and Johnson, P. D., 2012, “Modifications and Upgrades to the AFRL Turbine Research Facility,” ASME Paper No. GT2012-70084 (uploaded in SITIS 12/19/14).

4. Drawing, Slip Ring Hub Assembly (uploaded in SITIS 12/19/14).

5. Photos, Coverplates (uploaded in SITIS 12/19/14).

6. Photo, Rotor Instrumentation Ring (uploaded in SITIS 12/19/14).

7. List of 100-pin Hub Connectors (uploaded in SITIS 1/16/2015).

KEYWORDS: rotor, data acquisition, turbomachinery, turbine, telemetry, high frequency, high channel count, signal conditioning

AF151-072 TITLE: Ultralightweight Airframe Concepts for Air-launched Intelligence, Surveillance, and Reconnaissance (ISR) Unmanned Aerial Vehicles (UAVs)

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop an innovative aerostructural design to efficiently integrate a suite of radio-frequency (RF) antennas and weapons on an air-launched UAV.

DESCRIPTION: The Air Force Research Laboratory (AFRL) is exploring the opportunity for air-launched UAVs as a solution to augment future air dominance needs. The UAVs will be required to perform weapons delivery and RF functions, including wide-area search and track, signals intelligence, electronic warfare, and communications functions. The UAVs will be carried in, and launched from a mothership and possess the range capability to return to a safe recovery point. The mothership and mission establishes the following requirements and design constraints:

UAV (in captive carry):
- Length: 270 inches max
- Diameter: 30 inches max
- Max weight: 3,700 lb max
- Range: 2000 miles
- Endurance: 12 hours on station.

The stressing requirements for flight performance and RF functions will require a highly integrated UAV airframe design concept to minimize weight and drag, maximize RF performance, and maximize loiter time. In addition, the UAV will be required to reconfigure from a carry configuration to efficient configurations for cruise and loiter on station.

Structural weight can be minimized by the application of unitized bonded composites, or large resin-transfer-molded structural assemblies. Specific consideration should be given to the aerostructural design approach. Concepts that permit stowage of a large adaptive wing configuration that can be deployed to achieve a very high lift-to-drag ratio should be considered as a primary risk center for development. Aerostructural design requirements may require the use of aeroelastic control to improve drag efficiency and limit maximum structural design loads. Given that these vehicles will likely possess a limited life, design criteria should be tailored, the airframe design should be considered attritable, and cost should be considered a primary design driver.

To support the RF functions, the UAV will need a large number of antennas and arrays that are as large as possible for maximum gain and field of view. A primary technical challenge is to integrate the antennas with a UAV structure as efficiently as possible to minimize drag and maximize loiter and payload potential. Past and on-going research shows antennas that are conformal and part of the loadbearing structure minimize integration weight and drag penalties and provide extensive RF capability.

PHASE I: Product is a conceptual design of an air launched ISR UAV including definition of: reconfiguration approach, structural arrangement, antenna integration concepts, and antenna performance projections. Emphasis shall be placed on the definition of the aerostructural design, adaptive structures and antenna integration concepts. The goal is a design that maximizes range and endurance.

PHASE II: Develop a detailed structural design. Conduct structural element and antenna breadboard testing to validate the viability of high-risk design features. The program will demonstrate a large component that features the adaptive wing technology concept and validate its ability to actuate under structural load and characterize its aerodynamic performance in a wind tunnel.

PHASE III: Numerous military and commercial applications are foreseen for the integration innovations developed under this effort. Military applications include all size classes of ISR UAV. Commercial applications include aviation, transportation, and marine vehicles.

REFERENCES:

1. Callus, P., "Conformal Load-Bearing Antenna Structure for Australian Defence Force Aircraft," 2007.

2. Callus, P., "Novel Concepts for Conformal Load-bearing Antenna Structure," 2008.

3. Morphing wing, http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20070018202.pdf.

4. Oblique wing, http://en.wikipedia.org/wiki/Oblique_wing.

KEYWORDS: aircraft morphing, aeroelastic control, conformal loadbearing antenna structure, CLAS, composite structure, light weight aero designs

AF151-073 TITLE: Predicting the Flow Interactions of Modular Liquid Rocket Engine Thrust

Chambers

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a prediction capability for the flow interactions of adjacent thrust cells in a modular rocket engine.

DESCRIPTION: The design of a future liquid booster rocket engine based on an Aerospike configuration involves the use of modular thrust chambers. These thrust chambers will ultimately have mechanical, thermal and flow field interactions. This activity is an attempt to both model analytically the conditions relevant to these interactions and also to design and test a multiple of thrust cells, typically five, in order to establish a relationship between the analytical models and the experimental results.

One possible way to decrease the cost of liquid rocket engines is to decrease the chamber pressure for the combustion devices. Higher pressure affords higher efficiency for an engine but it comes at a higher production cost. One reason the cost scales with pressure is the complexity required of the turbomachinery to spin faster while keeping the weight to an acceptable level. Another reason is that higher pressure operation often results on higher heat loads to the walls of the combustion chamber which in turn requires more cooling to maintain mechanical integrity and hence more pressure drop on the cooling circuits.

This effort should focus on modular rocket engine concepts that operate at lower chamber pressures than state of the art oxygen rich-stage combustion engines and, if possible, using cooling schemes that can result in lower pressure drops than conventional regenerative schemes (i.e., transpiration cooling).

Either conventional or additive manufacturing can be proposed for the development of the individual thrust cells, injector and nozzles. It is expected that CFD will be used to complete the modeling of the flowfield interactions. Other relevant software packages can be used to determine the mechanical loads, thermal environments, etc.

The propellant combination will be LOX/Hydrocarbon with regeneratively cooled thrust chambers. Thrust levels and performance parameters will be based on a sector from a subscale engine with a total thrust of 50,000 lbf (sea level). The intent is to pressure fed the sector assembly during testing.

PHASE I: Establish baseline design for the individual thrust cells, i.e., injector, nozzle and igniter utilizing additive manufracturing techniques. Establish the anlaytical tools necessary to perform the required modeling and anlaysis of the individual thrust cell interactions. The analysis should verify thrust cells can handle the thrust loads and thermal environment surrounding the integrated assembly.

PHASE II: Manufacture thrust cells and associated components. Develop analytical models necessary to understand and predict interactions of the flow fields of adjacent cells, verify performance of an individual cell, and calculate the thermal and mechanical loads associated with individual cells and their interactions.

Individually test thrust cell to verify performance. Develop an integrated assembly and test cells to verify integrated performance and compare the results with analytical models.

PHASE III: This effort supports current and future DoD/NASA space launch applications. It will also support commercial space launch vehicle development.

REFERENCES:
1. Sutton, G.P., “History of Liquid Rocket Engines,” American Institute of Aeronautics and Astronautics, Reston, Virginia, 2006.

2. G.P. Sutton & O. Biblarz, Rocket Propulsion Elements, 7th Ed., John Wiley & Sons, Inc., New York, 2001, ISBN 0-471-32642-9.

3. D.K. Huzel & D.H. Huang, Modern Engineering for Design of Liquid-Propellant Rocket Engines, Vol 147, Progress in Astronautics and Aeronautics, Published by AIAA, Washington DC., 1992, ISBN 1-56347-013-6.

4. Richard Vander Veen, Roy Gentry, Joe Hoffman, “Design of Shrouded Plug Nozzles for Maximum Thrust,” AIAA Journal, Vol 12, No. 9, September 1974.

5. David Migdal, “Supersonic Annular Nozzles,” Journal of Spacecraft, Vol 9, No. 1, January 1972.

6. Marcello Onofri, “Plug Nozzles, Summary of Flow Features and Engine Performance,” University of Rome “La Sapienza”, Roma, Italy, January 2006.

KEYWORDS: modular rocket engine, aerospike engine, liquid rocket engine, design tool, modeling and simulation

AF151-074 TITLE: <u>Narrow Width Line of Detection</u>

TECHNOLOGY AREAS: Sensors

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OBJECTIVE: Develop a method to detect intruders crossing a line of detection with a maximum width of 1.5 meters (5 feet).

DESCRIPTION: This topic seeks to develop a line of detection (LOD) to be used for intrusion detection systems protecting critical Air Force assets on flightlines, launch facilities, and weapon storage areas. An LOD uses sensors to detect the presence of intruders (humans and vehicles) crossing a designated restricted area boundary around resources and assets protected by a security system. When someone crosses this boundary, an alarm is reported to a central console known as an annunciator so the security forces can react to apprehend the intruder. The LOD shall have a high probability of detection (Pd) for targets including people walking, running, crawling, and jumping and vehicles traveling at high or low speed when crossing through the LOD; however, the width of the detection area for the LOD shall be less than 1.5 meters (threshold) or 1 meter (objective). The LOD shall have a low probability of false or nuisance alarms and shall not detect people or vehicles outside the 1.5 meter width. The LOD shall be divided into sections with lengths of 100 meters or less with many sections connected to surround critical assets. The LOD shall provide a unique alarm indication to an annunciator for each sector using contact relays or XML messages.

The sensors used for the line of detection could use any phenomenology but must be compatible and not interfere with site operations, including running and moving jet and propeller aircraft, activities of maintenance crews and supporting operational vehicles, and running aerospace ground equipment (AGE). The aircraft, personnel, and equipment should be able to be within 1.5 meters of the LOD and not cause the sensor to create an alarm. Also, a vehicle or personnel shall be able to travel parallel (on either side of the LOD) without causing an alarm. In addition, the sensors shall be below or even with the ground or flightline surface. No part of the sensor in the detection zone can be above ground, and post mountings near a flightline are specifically excluded. The sensors shall operate in day/night conditions as well as all types of weather. Government materials, equipment, data, or facilities are not required.

PHASE I: Develop a preliminary design of the narrow width line of detection with all of the relevant sensor requirements. Conduct a study that describes the expected sensor performance. The sensor design and study should be of sufficient detail that a customer will be able to determine the compatibility of the sensor approach to their application.

PHASE II: Build a prototype narrow width line of detection sensor that meets the stated requirements, and demonstrate performance in a simulated operational environment. The demonstration sensors shall be installed in several surfaces including concrete, asphalt, and soil. The performance shall be evaluated against activities near the LOD and intruders either walking, running, crawling, or jumping and vehicles crossing the LOD. During the analysis, the Pd and false alarm rate (FAR) shall be determined.

PHASE III: The technology developed under this SBIR can transform both military and civilian intrusion detection systems. Discrete and reliable lines of detection are needed in many industries including power plants, refineries, and transportation facilities including airports.

REFERENCES:

1. Air Mobility Command Flightline Security Standards, Feb. 1999, http://www.wbdg.org/ccb/AF/AFDG/flightlinesecuritystandards.pdf.

2. “Protection the flightline and its resources,” 21 August 2012, http://www.afgsc.af.mil/news/story.asp?id=123314967.

KEYWORDS: line of detection, intrusion detection, flightline security, security system

AF151-075 TITLE: Strategic Hardening of Cold Atom Based Inertial Measurement Units (IMU)

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop an analytical model that will determine the effects of hostile and benign space environments on the performance of strategic grade IMUs. Assess the effectiveness of various hardening approaches including active compensation, and shielding.

DESCRIPTION: An analysis of adverse environmental and weapons effects on cold atom IMUs is required to assess viability for strategic applications and begin the development of hardening approaches for future systems.

This SBIR will develop a model capable of analytically assessing the effect of magnetic and electromagnetic fields (conducted and radiated), EMP generated affects, particulate radiation, vibration and shock on the performance of a cold atom based IMU. The model should be adaptable to various potential configurations of hypothetical CAIMU sensor systems and should include a system error model that includes all significant error contributors to IMU accuracy. Additionally, the analytical model should address the effectiveness of possible mitigation and hardening strategies such as active compensation and shielding.

The model application is intended to be limited to the sensor head portion of the IMU, including lasers and optics, but not electronics.

A method of experimentally verifying and validating the analytical model is also to be designed with development of a test plan that will be executed.

For Phase I, a physics-based analytical model will be developed. The model will enable analysis of the effects of 10 gauss peak to peak magnetic fields, 300 kRad radiation dose (proton - nominal 63 MeV or ionizing), 1E10 rads Si/sec prompt dose, 5 g rms 20 Hz to 2 kHz shock and vibration effects on cold atom interferometer inertial navigation sensors. The model will incorporate all significant errors that affect IMU accuracy. The model is to be used to estimate the impacts to navigational accuracy of these effects. The model software will be documented with explanation of modeling principles including algorithms employed. Functional flow and block diagrams of the software developed shall also be provided. A conceptual approach to experimentally verifying and validating the analytical model should also be presented, including preliminary design of the experimental setup with estimates of cost and schedule to accomplish the verification and validation work.

Phase II will broaden the scope of the model developed in Phase I to incorporate the capability to model methods for mitigating the impact of environmental effects. A test plan, incorporating the experimental approach for verifying and validating the analytical model, as presented in the Phase I effort will be developed. The experimental setup will be constructed and the validation and verification testing will be executed. The results will also be used to further refine the utility and accuracy of the model. Several mitigation approaches will be modeled and will be implemented in the experimental setup to validate the models capability to evaluate mitigation approaches. The model will be documented with descriptions of modeling principles, functional flow and block diagrams, algorithms employed, etc. A user manual will also be developed describing how to operate the software and required inputs, outputs, databases and operator actions. The model software, documentation and user manual will be a deliverable item to the government.

PHASE I: Develop a physics-based analytical model to enable analysis of magnetic field, electromagnetic (EM), particulate and EM radiation, shock and vibration effects on cold atom interferometer inertial navigation sensors.

PHASE II: Broaden the scope of the model developed in Phase I to incorporate modeling methods for mitigating the impact of environmental effects. Testing, incorporating the experimental approach for verifying and validating the analytical model, as presented in the Phase I effort will be developed.

PHASE III: Applicable to INS sensors for use in precision submarine navigation, commercial and recreational diving and personal INS systems that avoid issues with GPS outages in obscured environments. This capability is applicable to weapon systems, air, space and submarine vehicles.

REFERENCES:
1. “DARPA seeks to wean smart weapons off GPS with hybrid inertial navigation system-on-a-chip,” April 18, 2012, John Keller, Military and Aerospace Electronics, April 18, 2012.

2. “Cold Atom Gyros,” Todd L. Gustavson, Director of Advanced Sensor Development, AOSense, Inc., IEEE Sensors 2013 Tutorial, 11/3/2013.

3. “Six-Axis Inertial Sensor Using Cold-Atom Interferometry,” B. Canuel, F. Leduc, D. Holleville, A. Gauguet, J. Fils, A. Virdis, A. Clairon, N. Dimarcq, Ch. J. Borde, and A. Landragin, LNE-SYRTE, CNRS UMR 8630, Observatoire de Paris, 61 avenue de l’Observatoire, 75014 Paris, France; P. Bouyer, Laboratoire Charles Fabry, CNRS UMR 8501, Centre Scientifique d’Orsay, Batiment 503, Boite Postale 147, 91403 Orsay, France, 7 July 2006).

KEYWORDS: cold atom, interferometry, inertial, navigation, Bose-Einstein, autonomous inertial navigation, submarine navigation

AF151-076 TITLE: Advanced Solar Array for Dual Launch GPS

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: To develop solar array technology with substantial advances in stowed volume efficiency and specific power over the state-of-practice that enable/enhance various GPS alternative architectures and dual launch configurations.

DESCRIPTION: Alternative GPS architectures and launch strategies (dual launch manifest) that seek reduced system costs will require mass reductions of spacecraft bus components, such as solar arrays, to meet system level mass targets with acceptable margin. In addition, reduction of solar array stowed volume will open up system level trades that provide more design freedom. More design freedom will increase the likelihood of establishing a design that meets mission requirements. Conventional state-of-practice rigid panel solar arrays package very inefficiently (kW/m3), have relatively low specific power (W/kg), and have little design space to increase performance. Therefore, alternative solar array technologies are sought that substantially reduce the solar array mass and stowed volume. Proposers shall quantify expected improvements over current state-of-practice in stowed volume efficiency and specific power at power levels between 1 kW and 7 kW for a GPS orbit with 10-15 year lifetime. Target performance levels are >200 W/kg and >40 kW/m3. Proposed concepts should support integration of both currently available space qualified multijunction solar cells and thin, inverted metamorphic solar cells. Development is sought for the complete solar array (deployment mechanisms, structure, and solar panels). Historically, advanced technology insertion has proven difficult for DoD programs due to risk aversion and a strong desire to remain with technologies with significant heritage. Therefore, proposers shall establish a path to tech transition that overcomes these historical barriers for advanced technology insertion.

PHASE I: Design and develop prototype/concept to establish feasibility of the design and the realism of the performance predictions for the technology. Key aspects must be demonstrated during Phase I, through modeling and prototype fabrication, to warrant Phase II selection. Identify key technical challenges for Phase II.

PHASE II: Using the lessons learned from fabricating and testing of prototype in Phase I, design and fabricate a second-generation prototype concept clearly traceable to spacecraft integration. Desired performance metrics shall be clearly demonstrated on real hardware at a system level.

PHASE III: Technology developed will be applicable to all military and commercial space platforms. Expected benefits include increased payload mass and volume margin and more power for fixed resource allocation (mass).

REFERENCES:
1. Murphy, D., Eskenazi, M., White, S., Spence, B., "Thin-Film and Crystalline Solar Cell Array System Performance Comparisons," 29th Photovoltaic Specialist Conference, May 19-24, 2002. pp 782-787.

2. Breen, M.L.; Streett, A; Cokin, D.; Stribling, R.; Mason, A; Sutton, S., "IBIS (Integrated Blanket/Interconnect System), Boeing's solution for implementing IMM (Inverted Metamorphic) solar cells on a light-weight flexible solar panel," Photovoltaic Specialists Conference (PVSC), 2010 35th IEEE, pp.000723,000724, 20-25 June 2010.

3. Banik, J., Structural Scaling Metrics For Tensioned-Blanket Space Systems, PhD Dissertation, University of New Mexico, http://hdl.handle.net/1928/24293.

KEYWORDS: solar arrays, compact stowage, blanket solar arrays, inverted metamorphic solar cell

AF151-077 TITLE: <u>Reconfigurable RF Front-end for Multi-GNSS/Communication SDR Receiver</u>

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop a low SWAP reconfigurable RF front-end architecture for frequency band-agnostic handheld devices that would enable processing of multi-GNSS and Communication Band signals using COTS components for a software defined radio (SDR) application.

DESCRIPTION: The objective of this SBIR project is to investigate, recommend, prototype, and test reconfigurable RF front-end (RF FE) architecture for frequency band-agnostic processing that would enable a software defined radio (SDR)-based multi-GNSS receiver and communication device, with the goal of covering the entire GNSS requency range of 1160 MHz to 1610 MHz (modernized GPS, GLONASS, QZSS, and Galileo signals). A reconfigurable RF FE network should dynamically reconfigure the FE to process the appropriate frequency band of interest. This is especially relevant for the kind of re-programmability that would be needed for implementing a software-defined radio (SDR) receiver. Low power and small size objectives are for incorporating the reconfigurable FE in handheld devices.

The project should focus on successfully demonstrating how the FE network can be configured on the fly into a single-band, single-path RF circuitry in order to optimize the resources (power and antenna efficiency) for a communication & multi-band navigation SDR receiver that uses a reconfigurable multi-band antenna. A system using such a reconfigurable RFFE is expected to work with a reconfigurable multi-band antenna that is tuned via RF switches to work at different frequency bands.

Offerors are encouraged to work with established industry partners to leverage their proven expertise in the relevant areas. They should also clearly indicate in their proposals what government furnished property or information are required for effort success.

PHASE I: Conduct a comprehensive comparative assessment of COTS-based reconfigurable RF front-end (RF FE) network architectures, and make a recommendation about the best architecture. The study should evaluate architecture options with respect to complexity, processing load, ease of reconfigurability on the fly, and suitability for an SDR-based multi-band navigation and communication handheld device.

PHASE II: The selected company will design and build a COTS-based prototype of a reconfigurable RFFE network for a Software Defined Radio (SDR)-based low power small size device, and demonstrate how the RFFE network could be reconfigured on the fly into a single-RF path for a single frequency-band of interest- communication band or navigation band. The prototype and demonstration would use the recommended RFFE network solution from Phase I.

PHASE III: Implement the design using COTS components leveraging MEMS devices to be rapidly transitionable for use in an SDR-based communication and multi-GNSS navigation handheld military receiver. Commercialization of the proposed innovation should motivate partnerships with other GPS system contractors.

REFERENCES:

1. "RF front-end technology for reconfigurable mobile systems," by G. Boeck, D. Plenkowski, et al. in Proceedings of Microwave and Optoelectronics Conference, 2003, IMOC 2003.

2. “Reconfigurable RF Front-End for Frequency-Agile Direct Conversion Receivers and Cognitive Radio System Applications,” by E.E. Djoumessi and Ke Wu of Poly-Grames Research Center, Center for Radiofrequency Electronics Research of Quebec (CREER), Ecole Polytechnique de Montreal, C. P. 6079, Succ. Centre-Ville, Montreal, Quebec, Canada. Link: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5434205.

3. “RF Front End Is Reconfigurable.” Link: http://mwrf.com/mixed-signal-semiconductors/rf-front-end-reconfigurable.

KEYWORDS: RF processing circuitry, multi-frequency antennas, mobile antennas, mobile radio equipment, reconfigurable antennas systems

AF151-078 TITLE: Ephemeral Security Overlay for GPS

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a network-based security overlay for military GPS that provides enhanced security for GPS Critical Program Information (CPI) while relieving GPS devices from burdensome protection measures.

DESCRIPTION: Military GPS receivers are unlike any other cryptography-based system in the Department of Defense (DoD). Nearly every weapon system in DoD uses GPS, the host equipment must be unclassified, and military receivers are exported to over 55 authorized nations. GPS is a broadcast system, with receivers passively receiving the encrypted signal. The encryption does not primarily protect classified information, as a communication system does, but provides Transmission Security (TRANSEC) to support military exclusivity – ensuring U.S. and Allied forces have access to the signal with the assurance that an adversary does not. Furthermore, GPS utilizes “black” keys – encrypted keys that can be transmitted unclassified over the air. This adds a requirement that each receiver include a key decryption capability buried within a secure module protected by anti-tamper.

These security requirements for GPS place a heavy burden on GPS User Equipment to protect CPI within the receiver, driving up the Size, Weight, Power, and Cost (SWAP-C) of military receivers while exposing the CPI to exploitation should the receivers find themselves in enemy hands. With most GPS receivers now integrated into systems with tactical or strategic communications capability, and the advent of advanced Information Assurance (IA) techniques for protecting access to classified systems, a new approach is desirable that combines operational concepts, technology, and connectivity to enhance the protection of GPS CPI while reducing the hardware burden on military GPS receivers.

This SBIR will develop an ephemeral security overlay for fielded GPS receivers. The purpose of the ephemeral attribute is to eliminate permanence of the CPI within the GPS receiver – all critical data will exist temporarily and be removed automatically at the end of a session. Modern techniques to maintain control and allow access by the military receivers to the military signals should be evaluated, including location-based access (receivers purge data outside of an authorized region), biometrics (only authorized users may initialize a receiver), and advanced key distribution and protection concepts. The availability of a network should be assumed, and should form the foundation for the overlay architecture. No changes to the GPS satellites, GPS control segment, or GPS cryptography should be considered – instead, this architecture should be an overlay that augments the existing security architecture.

PHASE I: Develop an operations concept, architecture, and supporting technology for an Ephemeral GPS Security Overlay.

PHASE II: The selected company will design, test, and implement a prototype brassboard system to be tested in a laboratory environment.

PHASE III: The selected company will develop a prototype system to be integrated in multiple ground vehicles and tested in a GPS denied environment. Military application: GPS user equipment segment. Commercial application: Civilian (FAA) user equipment.

REFERENCES:
1. Indrakshi Ray and Mahendra Kumar, Towards a location-based mandatory access control model, Computers & Security 25, no. 1 (2006): 36-44.

2. Biometrics Technology Introduction, NSTC Subcommittee on Biometrics, http://www.biometrics.gov/documents/biointro.pdf, accessed 16 December 2013.

3. D. Faria and D. Cheriton, :No long-term secrets: Location-based security in overprovisioned wireless LANs, in Proc. ACM Workshop on Hot Topics in Networks, vol. 1, November 2004, pp. 212-222.2013.

KEYWORDS: PNT, electronic warfare, GPS, cryptography, information assurance

AF151-079 TITLE: Automated Terrestrial EMI Emitter Locator for AFSCN Ground Stations

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Create an automated system that identifies location of terrestrial and airborne transmitters that cause EMI interference with satellite downlinks.

DESCRIPTION: The Air Force is critically dependent on the Air Force Satellite Control Network (AFSCN) for satellite tracking, nominal on-orbit operations, launch and early orbit checkout, and anomaly resolution. AFSCN sites are subject to interference from terrestrial and aerial radio emitters and could potentially become jamming targets during potential future conflicts. The labor-intensive and high-latency radio interference monitoring capabilities available such as the AFSCN Link Protection System (ALPS) and direction-finder antenna suites, in conjunction with human-in-the-loop decision support systems, make it impractical to detect and respond to elusive and adaptive radio threats. This topic of solicitation will seek innovative automated solutions that will overcome the current limitations associated with ALPS; e.g., time latency and manpower required to localize radio interferences and thus, responsively mitigating operational risks of satellite operations. Specifically, the methodologies used in the ALPS should be leveraged in any proposed advances. Also relevant are potential capabilities to predict the impacts of radio interferences from terrestrial or aerial sources on space-to-ground-link-systems (SGLS). A technical challenge is how to accurately provide situational assessment for radio frequency interference and attribute it to a particular threat situation. This requires space domain understanding of threat conditions with possible courses of action. Providing output data in an intuitive fashion for operator understand should be considered.

The solution should automate the manual process by automatically using the azimuth and dBm values from ALPS and automatically calculate possible distances using operator input of possible emitter amplitude(s) and import a product as a kml or kmz into Google Earth on NIPR or SIPR.

This will cut down man hours (1-2 hours per stationary emitter, or 3-5 hours per aerial emitter) and allow research into source identifying the emitter much sooner and mitigate operational risk to satellite operations. Additionally, this will supplement ongoing space situational awareness during non-interference periods of operations and will help facilitate defensive space control operations during periods of interference.

PHASE I: Define use-case scenarios which take into account relative transmit powers, waveform structures, antenna patterns, relative geometries, and traffic patterns for both rogue radio emitters and satellite ground stations. Identify a set of autonomy solutions to improve the current ALPS capabilities. Conduct 3D simulation and visualization for radio interference localizations and alert generations.

PHASE II: Refine the Phase I results. Develop a proof of concept tailored for a variety of realistic interference conditions. Characterize SGLS performance for different rogue transmit antenna elevation angles, geographical distances, interference-to-signal ratios, bit-error-rates, and frequency separations between interference signals and SGLG bands.

PHASE III: If successful, develop the technology into add-on modular and integrate them into an operational system with assistance from DoD prime contractors.

REFERENCES:
1. http://www.schriever.af.mil/news/story.asp?id=123342861.

2. http://enu.kz/repository/2011/AIAA-2011-1628.pdf.

KEYWORDS: AFSCN, AFSCN Link Protection System, SGLS, radio interference, interference-to-signal ratios, frequency separation, elevation angles, rogue radio emitters, satellite ground stations, antenna patterns, relative geometries, traffic patterns, bit-error-rates

AF151-080 TITLE: Long Term Ultrastable Laser System for Space Based Atomic PNT

TECHNOLOGY AREAS: Space Platforms

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OBJECTIVE: Develop and demonstrate a frequency and intensity stabilized rubidium compatible laser that can operate through harsh conditions.

DESCRIPTION: Future atomic devices, such as atomic clocks and Inertial Measurement Units (IMU), will improve GPS performance and resilience, provide precision navigation and timing in denied environments, and increase security for communications. These atomic-based devices require very stable laser sources. This topic focuses on demonstrating a laser system that can provide high frequency and intensity stability in harsh conditions over the many years operating life of a sensor.

An ideal system should output >500 mW of light to the atoms (after required optical isolation, spatial filtering, frequency modulation, and optical path routing). This power would be stable to better than 20 microwatts. The laser system should be turnkey, able to lock itself and stay frequency locked to a Doppler free atomic transition and the laser line width should be narrower than the natural line width of the atomic transition. As a starting point, 100 kHz laser line width would be acceptable to many applications. The system should reliably maintain stable operation for 10 years or more. Current state of the art is only a few years and then only with significant power drift.

Current systems are generally based on diode laser technology. Diode lasers, as well as many other gain mediums, exhibit “mode hops” that entail large intensity and frequency excursions of a few percent in power and several GHz in frequency. Such excursions cannot be tolerated. The laser system here will need to be inherently and demonstrably mode hop free for 10 years or find some approach to predictively mitigate hops before they can cause discontinuity in the output such as in Reference 2. If the system departs from the design wavelength, automatic recognition and relocking will be required. If an individual laser source cannot meet the lifetime goals, then redundant sources should be used and a seamless handoff employed. Size, Weight, Power and Cost (SWaP-C) considerations are important therefore if something other than a direct diode approach is taken, such as a solid state laser or a frequency doubled telecom laser, then then the SWaP-C should be justifiable.

Clearly a 10 year test is outside the scope of a SBIR, so accelerated life tests should be considered. The system output should not deviate under vibrations, temperature swings, radiation dose, magnetic fields, or any other environmental conditions encountered in any space orbit as outlined below:
Temperature: -5 to 30 C, cycling at 2 C/hour
Vibration: 5 g rms 20 Hz to 2 kHz
Radiation: 300 kRad (Proton â€“ nominal 63MeV, or Ionizing), Prompt dose of 1E10 rads (Si)/sec dose rate)
Magnets: 10 gauss peak to peak fluctuations.

PHASE I: Research and design a solution for a stabilized laser system as described near 778, 780, or 852 nm (to work with Rb or Cs systems): a system with 1E-4 fractional intensity stability and long term frequency stability better than 10 kHz over many years.

PHASE II: Build the system described in Phase I and demonstrate its stability. Show mode hop mitigation if applicable. Lock it to an atomic transition and monitoring the frequency stability (Allan deviation) and intensity stability under harsh environments of changing accelerations, temperature, radiation exposure and magnetic fields over long time periods. Build a multiyear lifetime testing architecture.

PHASE III: Conduct multiyear lifetime testing.

REFERENCES:
1. Chuang, Ho-Chiao et al. Robust Tunable External Cavity Diode laser Using a Volume Holographic Grating for Rubidium Atom Cooling. 2010 International Conference on Optics Photonics and Energy Engineering.

2. Xu Zhouxiang et al. Long-term frequency stabilization system for external cavity diode laser based on mode boundary detection. Review Sci. Instr. 82 # 123110 (2011).

3. F. Allard et al. Automatic system to control the operation of an extended cavity diode laser. Review Sci. Instr. 75 #54 (2004).

KEYWORDS: laser cooling, optical clock, atomic clock, inertial navigation, atom interferometry, frequency standard, mode hop

AF151-081 TITLE: Novel, Collaborative Tipping and Cueing Methods to Exploit Multiple OPIR Sensors

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop collaborative tipping/cueing from any persistent or transient OPIR assets (e.g., SBIRS, other national overhead sensors) to other ISR assets, from initial detection to tracking and ground reporting, to enable improved target observation.

DESCRIPTION: SBIRS and DSP satellites continuously scan the globe, while other infrared sensors (including satellites, airborne, and ground-based assets) scan individual sectors of the globe or smaller coverage regions local to them. This effort would seek to tie together continuous global coverage with continuous or intermittent local coverage and develop a system of automated collaborative tipping and cueing among these assets.

The goal is to produce and collate additional information to support battlespace awareness or battlefield assessment for combatant commanders, or to produce additional technical intelligence that can be used to characterize event signatures. A collaborative cueing and tipping system would need to match asset availability, capability, and opportunity to view events to the presence of events, possibly during periods when multiple events are occurring simultaneously. The system would also need to operate under potentially-tight time constraints, such that short-duration events such as theater missile launches could be detected and viewed by additional cued systems in a time period conducive to an appropriate response from a theater-level commander.

The Phase II and III efforts will require knowledge of driving needs for one or both of the DoD and Intelligence Community, and access to sensitive program information on sensors, capabilities, and tasking. Phase II and III efforts may also require access to a facility that can process classified Secret data, as model and algorithm validation and demonstration shall be conducted using real OPIR and ISR data, if possible. The project will leverage this information to develop evolutionary ability to exploit broader space asset capabilities for core mission needs.

This tipping and cueing capability development is also applicable to real time disaster response, aircraft transfer between control points, tracking and routing ocean-based shipping, and real time weather support.

Innovation is required in, but not necessarily limited to, the areas of spectral band correlation techniques, moving object processing of under-sampled trajectories, and brightness variations with time.

PHASE I: Develop a model of coverage for persistent and transient OPIR and other ISR systems. Identify key metrics and likely scenarios. Develop CONOPS and algorithms to provide tipping and cueing to and from an arbitrary number of other individual assets with unique characteristics and access capability. As able and allowed by security restrictions, existing or planned sensor systems should be used.

PHASE II: Develop and tune tipping/cueing algorithms for use with real-time streaming OPIR and ISR data. Validate coverage model and algorithms, in part by creating manual tasking submissions and verifying appropriate decisions, resource management, and execution. Insert real OPIR/ISR data where possible.

Demonstrate capability to detect scenarios and perform appropriate cueing using OPIR and ISR data. Assess probability of detection/false alarm statistics for comparison with operational requirements.

PHASE III: Integrate capability into an appropriate command and control interface with real-time target assessment and cueing messages. Perform actual cueing between OPIR/ISR assets in the field.

REFERENCES:
1. Joint Publication 3-01, Countering Air and Missile Threats, 23 March 2012 (http://www.dtic.mil/doctrine/new_pubs/jp3_01.pdf).

2. http://www.dtic.mil/doctrine/doctrine/jwfc/surveillance_hbk.pdf.

3. DSP fact sheet. Online at http://www.losangeles.af.mil/library/factsheets/factsheet.asp?id=5323.

4. SBIRS fact sheet. Online at http://www.losangeles.af.mil/library/factsheets/factsheet.asp?id=20144.

KEYWORDS: OPIR, sensor automated cueing, infrared data, space sensor, battlespace awareness, technical intelligence, missile warning, layered sensing, integrated ISR

AF151-082 TITLE: Environmental Intelligence

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop data-processing methods and algorithms to produce novel environmental intelligence data products from overhead persistent infrared (OPIR) sources.

DESCRIPTION: Environmental Intelligence encompasses weather analysis and prediction, such as it pertains to altitudes below the lower stratosphere, short and long-term climatological data, and other surface-based and atmospheric events. The OPIR assets have the ability to provide real-time and persistent surveillance of the Earth"s surface and atmosphere in short-wave (SWIR) and mid-wave infrared (MWIR) bands. These data would serve as highly valuable augmentation to the current operational system of meteorological satellites such as DMSP, GOES, and other civil and international systems used by Air Force Weather Agency (AFWA). AFWA"s state-of-the-art operational methods for diagnosing and forecasting clouds globally are embodied in the Cloud Depiction and Forecast System II (CDFS II) algorithms and its Worldwide Merged Cloud Analysis (WWMCA) which utilize the current operational system of meteorological satellites. AFWA also sponsors the Coupled Assimilation and Prediction System (ACAPS) program which uses innovative satellite radiance data assimilation techniques to improve cloud diagnosis and numerical weather prediction. Conceivably both CDFS II and ACAPS could benefit from the judicious and innovative use of data from OPIR sources in advanced assimilation techniques suited for high resolution. This topic seeks innovative methods to exploit OPIR data for the purposes of producing accurate and useful Environmental Intelligence data products. Such methods should be suitable for deployment into research and development and operational facilities. Algorithms that generate unclassified products, even if generated from classified data streams, are of interest but not required. Some potential areas of research include:
1. Cloud-drift wind vectors
2. Aerosols, to include dust/sand storms
3. Cloud properties including microphysical and radiative characterization
4. Severe storm tracking, e.g., as squall lines and mesoscale convective systems
5. Fire detection
6. Gas flare monitoring
7. Volcano monitoring including plume tracking

8. Atmospheric electrical discharge identification
9. Tropical cyclone and surface wind monitoring

PHASE I: Develop environmental intelligence algorithms appropriate for use on OPIR data and evaluate them using simulated data and against current operational weather data sources. Define initial operational concept (OPSCON) and collection requirements for operational use: bandpass, look angle, frame rate, integration time, GSD, sensitivity, noise tolerance, etc.

PHASE II: Develop implementation for use with real-time streaming OPIR data. Test using operational data and varied sensor configurations to refine collection requirements and OPSCON for supporting DOD weather and climatological requirements.

PHASE III: Integrate capability into a civil/environmental data dissemination platform within the OPIR enterprise for near real-time dissemination to appropriate users.

REFERENCES:
1. Fully Automated Cloud-Drift Winds in NESDIS Operations, Nieman et al. 1997, BAMS http://adsabs.harvard.edu/abs/1997BAMS...78.1121N.

2. Cloud Detection Using Satellite Measurements of Infrared and Visible Radiances for ISCCP, Rossow and Garder 1993, J of Climate http://adsabs.harvard.edu/abs/1993JCli....6.2341R.

3. Analytical approach to estimating aerosol extinction and visibility from satellite observations, Lee et al. 2014, Atm Env. http://adsabs.harvard.edu/abs/2014AtmEn..91..127L.

4. Improved detection of airborne volcanic ash using multispectral infrared satellite data, Ellrod, Connell, & Hillger 2003, JGRD, http://adsabs.harvard.edu/abs/2003JGRD..108.4356E.

5. CHIRP program lessons learned from the contractor program management team perspective, Pang et al., 2012 IEEE. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6187278&tag=1.

6. (Reference was removed on 1/13/15 because it is limited distribution and is not publicly accessible at this time.)

7. Auligne, T., A. Lorenc, Y. Michel, T. Montmerle, A. Jones, M. Hu, and J. Dudhia, 2011: Toward a new cloud analysis and prediction system. Bull. Amer. Meteor. Soc., 92, 207-210.

KEYWORDS: environmental intelligence, OPIR, infrared data, algorithm, space sensor, weather analysis and prediction, climatology

AF151-083 TITLE: Post Processing of Satellite Catalog Data for Event

TECHNOLOGY AREAS: Information Systems

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OBJECTIVE: Research and develop new ways to better determine what satellite orbital events are most critical to monitor and provide courses of action.

DESCRIPTION: When the space fence comes on line, it is estimated that the catalog will grow to 100,000 objects. In addition, the new High Accuracy Catalog (HAC) is expected to produce an estimated 400,000 element sets a day. As these two efforts come on line, the operator will soon be presented with 15,000 conjunctions a week to screen and monitor. With each conjunction the operator must determine the likelihood of the conjunction, the associated risk level, and the appropriate course of action. When determining the likelihood of a conjunction, today, the operator primarily considers two factors: probability of collision and miss distance. Each of these metrics has their own inherent problems. Miss distance cannot be solely considered since two conjuncting assets may have a miss distance less than 20 km however if the covariance matrix for each object is small then the risk factor of the conjunction is relatively small. Conversely, the miss distance could also be large, but if the covariance matrix for one of the objects is larger than the miss distance between the two objects then the conjunction still has a relatively high risk factor. There are similar concerns when considering probability of collision. In addition a covariance matrix does not fully take into account raw sensor data and its biases. Typically the raw sensor data is fused into a flawed derived orbital product. A low probability of collision can result from both an unlikely event and a large covariance matrix. Physical object characteristics need to also be considered. An active asset conjuncting with a large secondary object is much more critical than two rocket bodies conjuncting and likewise two rocket bodies conjuncting is more important to track than say two small <10 cm pieces of debris. Each of those conjunctions has vastly different courses of action. The first conjunction has a direct impact on the mission and may require the asset to maneuver. The second conjunction is less critical than the first however it is still important to track since it has the potential to create a large amount of new debris that could later affect the mission. The third conjunction is of very little importance. This is a very involved process for the operators to conduct against the hundred or so conjunction events currently seen each week. This is an impossible task for the operators when considering 15,000 events a week. Methods need to be developed to determine which of those conjunctions are most critical and probable. Using raw sensor data feeds along with better use of data once catalog is processed will ease this problem. A capability needs to be developed that will filter the information presented to the operator down from the 15,000 conjunctions/week to only the conjunctions with high risk factors and impact factors. The capability also needs to be very dependable in the sense that the operator needs to be able to trust that the system is presenting to the operator the most likely and highest risk conjunctions, and not filtering out any events that will eventually be an issue.

PHASE I: To solve this multifaceted problem, the initial prototype should demonstrate the ability to ingest individual sensor data, process it and infer statistics from actual sensor measurements as opposed to simply processing orbital elements. In addition, smarter use of data mining and filtering approach, along with quantitative analysis should be used to reinforce validity of the approach chosen.

PHASE II: Interface descriptions will be supplied to Phase I awardees at Phase II proposal submission. The system shall in real time ingest real sensor data from at least one operational sensor, infer statistics, use data mining and intelligent filtering along with quantitative analysis to demonstrate significant improvement over current systems.

PHASE III: The technology developed during Phase II should be transitioned to an operational customer. The system shall mature Phase II to include real-time ingestion of multiple operational sensors' raw data feed.

REFERENCES:
1. Center for Space Standards and Innovation Website, http://www.celestrak.com/.

2. Automation Issues for Satellite Operations,
http://web.mit.edu/aeroastro/www/labs/ASL/satellite_autonomy/satellite_autonomy.html.

3. Filtering techniques for orbital debris conjunction analysis,
http://repository.tudelft.nl/view/ir/uuid%3A932a271a-9b2c-4c5d-aeac-862528ea62b0/.

4. Operating characteristic approach to effective satellite conjunction filtering,
http://www.centerforspace.com/downloads/files/pubs/AAS%2013-435.pdf.

5. Integrated Modeling of Perturbations in Atmospheres for Conjunction Tracking,

http://www.amostech.com/TechnicalPapers/2013/ASTRODYNAMICS/KOLLER.pdf.

6. Cheng, Y., DeMars, K., Jah, M., (2014). Collision Probability With Gaussian-Mixture Orbit Uncertainty. AIAA Journal of Guidance, Control, and Dynamics, Vol. 37, No. 3, pp. 979-985.

KEYWORDS: defensive space control, space situational awareness, conjunction analysis, covariance

AF151-084 TITLE: High-Temperature, Radiation-Hard and High-Efficiency DC-DC Converters for Space

TECHNOLOGY AREAS: Space Platforms

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OBJECTIVE: Investigate advancements required to achieve high-temperature, high-efficiency and low-specific-mass DC-DC converters for spacecraft.

DESCRIPTION: Spacecraft power management and distribution (PMAD) systems use DC-DC converters for bidirectional energy transfer from the batteries. They are also used for down converting the energy produced by the solar arrays for delivery to the various loads on the spacecraft. While these converters traditionally operate at temperatures around 80 degrees centigrade, with convertor efficiencies ranging from 80 percent to 90 percent. Advanced technology switching devices that are becoming available will allow high-temperature operation and reduced switching losses. These devices, such as GaN HEMTs or SiC JFETs, have been shown to be inherently radiation hard, which should increase the overall converter hardness and reduce the radiation shielding requirements.

The challenge for this technology development is to demonstrate that a DC-DC converter can be developed to operate with power stage semiconductor switch junction temperatures between 200 and 250 degrees centigrade. The DC-DC converter should be suitable for use on large communications spacecraft with converter efficiencies greater than 95 percent, and specific power of 1kW/kg. We are primarily interested in large satellites so the converter modules should be scalable for use in 5 to 30 kW power systems; however, supporting smaller platforms (<100 kg) is also of interest assuming we maintain flexibility to scale to larger systems. There are many applications for DC-DC converters in spacecraft with a different input voltage and one or more output voltages. One up-converting application would be to boost the voltage of a Nickel-Hydrogen or Li-Ion battery to match that of the spacecraft bus. For this application input voltages may vary from the 30 to 50 VDC range and the output voltage would be in the 70 to 120 VDC range. The specific input voltages and output voltages would depend upon the spacecraft power system design, which could vary with each spacecraft prime contractor. A second application of DC-DC converters would be to convert the spacecraft bus voltage to voltages acceptable for each payload element. Many payloads have DC-DC converters that have multiple output voltages. Typical output voltages are +/- 1.0, 5, 10, 15 VDC. The design must provide high efficiency at all points of load. The technology proposed should be capable of performing at least one of these two converter functions in a spacecraft application.

The DC-DC converter should be capable of supporting a 15-year mission in Geosynchronous Earth Orbit (GEO) or Medium Earth Orbit (MEO) and 5 years in Low Earth Orbit (LEO) after storage on the ground for 5 years. It should function after 500 kRad (Si) total dose, be immune to dose rate and single event latchup, and not upset at a single event LET lower than 20 Mev/mg/cm2.

PHASE I: Design a high efficiency, radiation hard, power processing module to operate at greater than 200 degrees centigrade. The power processing module shall be scalable for use for primary bus regulation in a spacecraft power system and provide high efficiency at all load points.

PHASE II: Demonstrate a breadboard with a delivered output power processing module. Demonstrate the radiation hardness of all key components.

PHASE III: Technology developed will be applicable to all military and commercial space platforms. Expected benefits include increased payload mass and volume margin and more power for fixed resource allocation (mass).

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KEYWORDS: DC-DC converter, high temperature, power, spacecraft

AF151-085 TITLE: <u>Advanced High Specific Energy Storage Devices Capable of long life and >300 Whr/kg</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop an energy storage device that will meet life and power requirements for DoD Spacecraft and demonstrate specific energy > 300 Whr/kg and be capable of sustaining 1C discharge rates.

DESCRIPTION: Mass of spacecraft components, especially of the power system, can be a significant portion of the overall spacecraft mass. In order to reduce the mass required for spacecraft battery and to meet exponentially increasing satellite communications capacity requirements to support tomorrow's warfighters, the U.S. Air Force is interesting in supporting advanced energy storage cell development. State-of-the-art Li-ion cells have limited life which may not be compatible with 5 year ground storage followed by 15 years of operational lifetimes for DoD satellites deployed in geosynchronous earth orbit, or with up to 60,000 charge/discharge cycles needed for low earth orbiting satellites. Degradation of the electrodes and electrolytes over time and with each charge/discharge cycle prevent timely insertion of this technology into DoD space-based assets. Additional concern about the overall specific energy of current technology may limit applicability to Air Force assets especially for MEO or GEO applications.

Because of the increasing need for power and the emphasis of reducing size and weight of power system components, there is a need to develop advanced energy storage systems that are capable of specific energy > 300 Whr/kg and capable of supporting life cycle and power requirements, mentioned above, for DoD spacecraft. It is expected that innovative materials, new chemistries, cell designs, or combination of all three are needed to achieve higher energy density cells. Several potential routes have shown promise, including Si-based anodes, layered metal oxide cathodes, CNT or other additives, and solid state chemistries and designs to name a few. These and other methods for improving the ultimate life of energy storage devices while meeting 300 Whr/kg on the cell level, discharge rates of 1 C, and cycle life of 5000 at 70 percent depth of discharge will be considered for this technology development.

The goal of this technology development is to design, develop and test an advanced design for energy storage cells, which are capable of fifteen year service life in higher altitude orbits with a minimum of 5000 charge/discharge cycles and appropriate calendar life and rate capabilities while demonstrating 300 Whr/kg specific energy density.

PHASE I: Demonstrate a feasibility of the proposed concept through materials analysis and preliminary testing. Show pathway to achieve energy density > 300 Whr/kg, cycle life, and rate requirements.

PHASE II: Demonstrate proof of concept with the fabrication and testing of an advanced cell design meeting the required metrics outlined in this topic.

PHASE III: High energy density energy storage systems with long life are needed for all DoD spacecraft.

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KEYWORDS: batteries, high specific energy, space power, solid state, cathodes, anodes, electrolytes

AF151-086 TITLE: <u>A Practical Incoherent Scatter Radar</u>

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Design of components for an ionospheric Incoherent Scatter Radar (ISR) with costs that enable the operational use for DoD environmental sensing and compete favorably with satellite based solutions.

DESCRIPTION: Incoherent Scatter Radars use the principle of Thomson Scattering (TS), which is the elastic scattering of electromagnetic radiation by a free charged particle. As RF waves travel through the ionosphere and scatters from electrons in the ionosphere, the TS phenomena governs their behavior and can be captured to provide scientific data to the warfighter concerning atmospheric density, temperature gradients, ion composition, drift velocity and ground station/receiver distance. However, further development of the advanced technology is needed in order to effectively capture this data and transmit the information back to the warfighter. The reference design is the NSF AMISR (Advanced Modular Incoherent Scatter Radars) with estimated cost of about $20M/copy.

This topic solicits concepts for innovative approaches to Incoherent Scatter Radar that will make practical (cost, logistics, power, data processing) a worldwide network of radars that can sense the ionosphere both below and above the F2 peak in ion density. The ultimate objective is to lower costs (build, siting, sustainment, etc.) to where a network can be deployed for less cost than a satellite such as C/NOFS ($150M est) with superior performance.

Since a working prototype is likely outside the scope of a Phase II SBIR, this topic calls for concepts and designs such as: a complete system design, a breakthrough enabling component, RF simulation tools that would enable the exquisite simulation of a system before manufacture, or other approaches that would advance the objective. Specific performance objectives are: for density above 10^5/cc and range less than 600 km, measure to 10 percent, the ion composition and respective ion densities, electron and ion temperatures, and ion drift velocity. Capability beyond 600 km, and below 10^5/cc will be a basis for competition. Concepts should not be limited to traditional ISR formats and capabilities, for instance distributed and bi-static systems may be suggested.

PHASE I: A comprehensive description of the approach focused on demonstrating feasibility is the main objective of the Phase I effort. The complete innovative ISR system should be designed and described at the component level, and the most expensive components identified. Creative technical solutions in bringing the cost down, and upgrading technical capabilities of these components should be described.

PHASE II: A reference point ISR design, with cost and performance evaluation, should be demonstrated. If the design identifies new and unique technology needs, then subsequent component development should be accomplished during this phase. If more than one Phase I proposal is awarded then multiple Phase II awards could reduce the cost of the overall system. Design, construction and testing of these innovative components would be a main objective of the Phase II effort.

PHASE III: Develop, construct and test a prototype ISR to demonstrate ISR capabilities in an operationally relevant environment. Integrate the cost-effective components from the Phase I and II development efforts into a fully integrated working prototype. Project cost estimates up to 12 ISR production units.

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2. Final Report of the Alaskan Diagnostic Radar Panel, Panel Co-Chairmen: William E. Gordon and Brenton J. Watkins. Sponsored by the High Frequency Active Auroral Research Program, Air Force Research Laboratory, Hanscom AFB, MA, 17 Aug 2000.

KEYWORDS: radar, ionosphere, incoherent-scatter, space-environment

AF151-087 TITLE: Optimal SSN Tasking to Enhance Real-time Space Situational Awareness

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US

Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop and exhibit scalable & extensible technologies that would enable information-based centralized tasking & sensor-based task redistribution of a modernized Space Surveillance Network (SSN) in order to improve Space Situational Awareness (SSA).

DESCRIPTION: Since the launch of Sputnik I, the U.S. Air Force has been interested in monitoring Earth orbiting objects. With this interest, a worldwide network of (primarily) radar and optical sensors was piecewise developed, transitioned, and integrated into a system that is now known as the Space Surveillance Network and a global tasking center, the Joint Space Operations Center (JSpOC). The SSN has the mission of detecting, tracking, cataloging and identifying artificial objects orbiting the Earth, including active and inactive satellites, spent rocket bodies, or fragmentation. However, much of the architecture and operations behind this critical system are limited and outdated including: 1) 24-hour tasking cycle typically via email or stove-pipe mechanism, 2) ad-hoc reactionary tasking via phone, 3) minimal feedback to JSpOC on missed tasking or abnormal detections, 4) little to no information sharing between sensor sites, 5) tasking typically based on set return rate, not information gain expected, and 6) sensor sites do not return possibly beneficial information such as covariance, observation time, observation quality, or sensor specific feature data, such as radar cross-section and visual magnitude.

The SSN is in need of innovative techniques and approaches to leverage a future net-centric or grid-enabled infrastructure not bound by the current system limitations. This includes the ability to optimally task sensors such that the maximum information content is returned, Such capabilities would contribute to one or more of the following:
1) Enable real-time information-based tasking and scheduling of distributed, heterogeneous sensors to include real-time feedback
2) Enable the net-centric sharing and utilization of knowledge between sites within a sensor system
3) Enable the prioritization and distributed de-confliction associated with routine and contingency tasking in support of SSA, Space Force Enhancement, and Space Control
4) Enable the distinction between and integration of dedicated, collateral and contributing sensor sites and systems.

As appropriate, approximate Key Performance Parameters (KPPs) will include:
a) Time from central tasking to acknowledgment of receipt (Goal: <1 hour)
b) Percent of accepted taskings successfully performed (Goal: >95 percent)
c) Time from collect to data delivery (Goal: <1 hour)
d) Time from missed collect to report (Goal: <1 hour)
e) Time from site outage or tasking conflict to central alert (Goal: <30 minutes)
f) Time from alert of site outage to successful redistribution of tasking to remaining sites (Goal <30 minutes)
g) Given a set number of sites and a number of Earth orbiting objects, average max axes of position error (Goal: <15 km) while maintaining a specified revisit rate on a subset of objects

Desirable solutions would (a) be compatible with the current JSpOC Mission System (JMS) baseline, such that future integration of the algorithm would fit into the JSpOC infrastructure, and (b) include a hi-fidelity model of the SSN sensors, specifically sensor locations and characteristics.

PHASE I: Develop a limited scope, proof-of-concept automated SSN tasking demonstration that contains one or more of the capabilities described above. Phase I should also include a detailed design of a Phase II implementation. This design should describe how this system would be integrated with the output of maneuver detection and space object conjunctions algorithms. Scalability of design is key.

PHASE II: Phase II would extend the Phase I prototype and develop a proof-of-concept demonstration at a higher technology readiness level using live, net-centric data. A demonstration using actual network sensors would be highly desirable. The technologies derived from this will be targeted as JMS Post Increment 2 applications that will be matured within the AFRL Applications Research Collaborative Application Development Environment (ARCADE).

PHASE III: This topic is in line with the Joint Space Operations Center (JSpOC) Mission Systems (JMS) long term requirements for real-time automated SSN tasking. The initial target customer for this technology is the SMC/SY JMS Program Office and the Phase III will focus on transitioning developed capability.

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KEYWORDS: Space Surveillance Network, network scheduling, space situational awareness

AF151-088 TITLE: <u>Development of Ultracapacitors with High Specific Energy and Specific Power</u>

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop an ultracapacitor with specific energy > 50 Wh/kg, specific power > 10 kW/kg, and cycle life greater than 500,000 that can operate from -40 degrees C to +80 degrees C.

DESCRIPTION: The need for efficient energy storage systems in space platforms is paramount as expected lifetime and power needs continue to increase. Ultracapacitors have several advantages over traditional batteries, including cycle life in excess of 500,000 and extremely high charge/discharge rates with little to no degradation to cycle life. Additionally, better performance over a wider temperature range may allow distributed power architectures without the use or need of active cooling/heating, reducing mass and power consumption. However, ultracapacitors do not have high specific energy. Current production ultracapacitors are < 10 Wh/kg. For certain spacecraft applications, pulsed power profiles can be expected. These high power, short duration events may be deleterious to the lifetime of a traditional battery. To maximize end of life battery performance, the Air Force would like a spacecraft power system architecture that includes an energy buffer such as an ultracapacitor in the electrical power system at the location of these intermittent loads to ameliorate the effects of short duration high rate discharge cycles on the batteries. Because of pulsed power demands, spacecraft wiring harness must be sized to supply the high currents that these loads require adding significant mass to the spacecraft wiring harness. The location of an energy buffer at these loads (distributed energy storage) would allow spacecraft designers to size the power supply wiring for the average load required by the payload reducing wire size and mass.

Examples of peak loads are:
1) An electric thruster used for station-keeping or attitude control. Electric thrusters used in this manner would have step loads in the range of 1 kW for durations ranging from a few seconds to a maximum of one minute.
2) Ordinance firing loads which are in the range of 250 amps with duration of 250 milliseconds.
3) Event driven high power RF transmitters, which burst data for short durations. These transmitters would have step loads up to 1 kW for durations of one to five minutes.

The end goal of this technology will be as a distributed hybrid energy storage system with the capability of supporting a 15-year mission in Geosynchronous Earth Orbit (GEO) and five years in Low Earth Orbit (LEO) after five years of ground storage. In order for the ultracapacitor distributed energy storage architecture to be feasibile, it is required that the ultracapacitor have specific energy > 50 Whr/kg, specific power > 10 kW/kg, cycle life of > 500,000, and operating range of -40 degrees C to +80 degrees C.

PHASE I: Develop, evaluate, and validate innovative materials for use in an ultra-high specific energy density ultracapacitor while demonstrating good specific power and cycle life.

PHASE II: Optimize the materials and processes learned from Phase I to produce a prototype ultracapacitor with demonstrated specific energy density > 50 Wh/kg, specific power > 10 kW/kg while demonstrating high cycle life (>100,000) and high charge/discharge capabilities and temperatures as low as -40 degrees C.

PHASE III: All DoD spacecraft require some form of energy storage. The use of distributed ultracapacitors to meet pulsed power demands with high specific energy and power and wide operating temperature window can potentially be enabling for high power missions.

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KEYWORDS: ultracapacitors, supercapacitors, high specific energy, distributed energy storage, hybrid energy storage

AF151-089 TITLE: Radiation Hardened Digital to Analog Converter

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US

Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop & commercialize a radiation hardened (RH) Digital to Analog Converter with a minimum 12 bit resolution, 2x1e9 samples per second (2GSPS), 70dB Signal to Noise Ratio (SNR), & 80dB Spurious Free Dynamic Range (SFDR), for space applications.

DESCRIPTION: Demand for digital devices is continually increasing as technology developments push their capabilities. The telephone, which started out as a non-portable analog device, has become one of the most common digital computing systems in use with the development of the smartphone. Digital computers have dominated the market over analog computers due to speed, size, cost, etc. However, while digital processing offers many advantages over analog processing, analog devices cannot be eliminated completely. One major area still dominated by analog is data transmission. Data is commonly transmitted and received over radio frequency (RF) waves. This includes modern telephone systems, radio broadcasts, military devices such as RADARs, satellite communications, etc. While the data being processed inside each of these is digital, the data coming in and going out is still analog.

In order for analog data to be digitally processed or for digital data to be broadcast over an analog wave, there must be bridges between analog and digital. These bridges consist of Analog to Digital Converters (ADC) and Digital to Analog Converters (DAC). As technology has progressed, the need for ADCs and DACs with higher resolutions, better Signal to Noise Ratios (SNR), and faster sampling rates has greatly increased. Also, with the development of smaller, portable devices, the size, weight and power of these ADCs and DACs needs to be reduced.

The focus of this topic is the DAC for space applications. Current RH DACs have about 12 bit resolution, and operate in the Mega-Samples per Second (MSPS) range. Commercial DACs (Non-RH) can have 16 bit resolutions while operating in the GSPS range. There is a need for good resolution (at least 12 bits), high speed (at least 2GSPS), RH DACs to support new satellite developments. These DACs must balance the tradeoffs between speed, resolution, noise, and SWaP. The SNR should be 70dB or better and the SFDR should be 80dB or better.

The radiation-hardness requirements for the RH DAC are:
Effect: Units: Level:
Total Ionizing Dose rad(Si) 10e6
Single-Event Upset Err/bit-day 10e-10
Single-Event Latchup None
Dose-Rate Upset rads(Si)/s 10e10
Dose-Rate Survivability rads(Si)/s 10e12

Proposals should clearly indicate how the result of the effort would be shown to improve the MILSATCOM and GPS system''s capabilities through a test and validation plan. Testing and validation of risk reduction components of the overall effort in Phase I is encouraged.

Offerers are encouraged to work with MILSATCOM and PNT system prime contractors to help ensure applicability of their efforts and begin work towards technology transition.

Offerers should clearly indicate in their proposals what government furnished property or information are required for effort success. Requests for other DoD contractor intellectual property will be rejected.

PHASE I: Design and simulate an RH, high speed DAC for space based MILSATCOM & GPS applications. Other available metrics such as device uniformity, endurance, reliability, commercial viability, and design flexibility; should also be considered to design the most promising technology.

PHASE II: The selected company will partner with an appropriate foundry to produce working prototypes that are suitable for space applications then test and evaluate the prototypes for reliability and radiation hardness. Phase II efforts should include ensuring compatibility with CID supporting overall payload and space vehicle reference designs as part of their commercialization effort.

PHASE III: The selected company will build and commercialize an RH DAC for space applications. This will include QML qualification.

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KEYWORDS: digital to analog converter, DAC, CID, component interface descriptions

AF151-094 TITLE: <u>High Power Density Structural Heat Spreader</u>

TECHNOLOGY AREAS: Space Platforms

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OBJECTIVE: Develop a high performance structural heat spreader to efficiently spread the high heat flux of next generation GaN Power Amplifier to a value low enough for the thermal system to handle.

DESCRIPTION: Current thermal management of solid state power amplifiers (SSPAs) in space is limited in its ability to spread power densities from the channels of active power amplifier (PA) device to the large area thermal radiators required for ultimate rejection of heat to space. One area of interest for improvement in the transport of heat from source-to-sink is the heat spreader beneath the high power density GaN PA packaged device. Current power densities at the bottom of the PA device can exceed 62 W/cm2 and are expected to climb to values >1400 W/cm2 in the next five to six years. At these expected power densities, it is apparent a new high power density heat spreader will be required to bridge the gap between future expected power densities and the power densities our current systems can handle.

The High Power Density Structural Heat Spreader shall provide a reduction in power density by almost 250 times. Future power densities of GaN PA devices will exceed 1400 W/cm2 (600W over 0.635 cm x 0.635 cm). It is desired to have a heat spreader that can evenly distribute this heat to the heat sink with a resulting heat flux of no more than 62 W/cm2 (threshold) to 6.2 W/cm2 (objective). The resultant temperature drop across the heat spreader from (hot spot to bottom of the spreader) shall be no more than 25 degrees C (threshold) or 10 degrees C (objective). At a minimum the heat spreader must accommodate one heat source; however, we are also interested in technologies that can be scaled up to the panel level and accommodate multiple heat sources. Finally, since mass is critical for all space systems, low mass solutions that provide structural support are of interest.

The high power density heat spreader shall operate in a space environment (vacuum and no gravity), as well as on Earth in any orientation with respect to gravity for ground testability. At a minimum, the heat spreader shall meet the performance goals over an operating temperature range of 0 degrees C to 80 degrees C and a survival temperature range of -60 degrees C to 100 degrees C. However, operational temperatures up to 150 degrees C are also of great interest. In addition, please be sure to address the thermal induced stress on the heat spreader after thermal cycles in a specific application as this will vary depending on the mission. Passive approaches that require no power are preferred, but active, low power approaches will also be considered.

PHASE I: Develop conceptual designs of the hardware based on preliminary analysis. Demonstrate by analysis and/or test the feasibility of such concepts and that the approach can meet all of the performance requirements stated above in the Phase II development effort.

PHASE II: Demonstrate the technology developed in Phase I. Tasks shall include, but are not limited to, a demonstration of key technical parameters that can be accomplished and a detailed performance analysis of the technology. The culmination of the Phase II effort shall be at least one prototype unit delivery for validation testing.

PHASE III: The proliferation of GaN power amplifiers will likely offer a wide range of commercialization opportunities for RF based systems including communication satellites, aerospace applications, and other commercial communication systems.

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KEYWORDS: space platforms, GaN Power Amplifiers, heat spreader, high power, spacecraft structures, thermal control, thermal management

AF151-095 TITLE: 40 Percent Air Mass Zero Efficiency Solar Cells for Space Applications

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and demonstrate radiation-hard space solar cells with Air Mass Zero (AM0) efficiencies greater than 40 percent.

DESCRIPTION: Solar cells with higher efficiencies are needed to reduce array mass, stowed volume, and cost for Air Force space missions. The current state of the art crystalline multijunction solar cells and Inverted Metamorphic (IMM) solar cells are limited by the increasing material and structure complexity to a maximum conversion efficiency of approximately 35 percent Air Mass Zero (AM0). Thus, consideration must be made for new advancements and concepts which push photovoltaic technology to new limits and higher performance. The desired new solar cell would be lightweight, and radiation hardened, with emphasis on improved performance metrics at the solar array level (>500 W/Kg) over current state of the art devices. The goal for the new approach would be >40 percent efficiency AM0. Technologies involving organic-based designs are not expected to be feasible.

The overall goal of this solicitation is to develop innovative technology solutions for ultrahigh efficiency solar cells. In addition to cell performance, the Air Force Research Laboratory is also interested in realizing a cost-effective design. System level array and integration issues should be considered in the technology design.

The technology should be capable of supporting a 15-year mission in Geosynchronous Earth Orbit (GEO) or Medium Earth Orbit (MEO) and five years in Low Earth Orbit (LEO) after five years of ground storage. Specific considerations should include a radiation environment as called out in the AE9 (electron)/AP9 (proton) models. On-orbit temperatures will vary by orbit; generally, consider the extreme case at GEO of plus/minus 180 degrees C.

PHASE I: Develop innovative approaches and validate concepts for producing thin flexible ultra high efficiency space solar cells.

PHASE II: Apply the results of Phase I to develop a prototype demonstration of the production process.

PHASE III: Optimize production processes for high yield. Develop and conduct engineering confidence tests to ready technology for space qualification.

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KEYWORDS: high-efficiency solar cells, thin multijunction solar cells, space power, solar arrays

AF151-096 TITLE: <u>Selecting Appropriate Protective Courses of Action when Information-Starved</u>

TECHNOLOGY AREAS: Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: To develop algorithms, processes, and/or mathematical constructs that enable the selection of appropriate courses of action, even in the face of insufficient or low-quality data and information, in a congested and/or contested space environment.

DESCRIPTION: Our U.S space systems operate in an extremely harsh space environment. Additionally, the space environment, and in particular the Geostationary orbit, is becoming increasingly congested and contested. To ensure the continued operation of the Air Force's global space missions (Missile Warning, Military Satellite Communications, and Precision Navigation and Timing) we require space systems capable of acting/reacting within the timelines dictated by expected hazards and threats. However, this protective capability must also be properly balanced against mission requirements and system resource limitations, to prevent the unnecessary depletion of said resources or impacts to the mission (e.g. ambiguous sensor readings lead the satellite to maneuver which in turn reduces the system's station keeping capability, effectively shortening the satellite's service life).

The Air Force Research Laboratory believes that enabling these protective responses at a temporally effective pace will require increased levels of system autonomy to identify, assess, recommend, and eventually choose, plan and execute appropriate protective courses of action. AFRL also believes that, similar to all other warfighting domains subject to "the fog of war," that operators and (eventually) systems will have to make these choices in the presence of incomplete and/or low quality sets of data and information. AFRL's efforts to enable more autonomous space systems, is broken into the four following, yet highly coupled, areas:
1) Sensor Data Fusion: Integration of data from multiple sources, in order to properly assess the situation. The data can be from on-board sensors and satellite payloads, in addition to external sources of information (such as Space Situational Awareness information products from a Space Operations Center).
2) System Management: Housekeeping operations to keep the space vehicle operating. Examples include controlling the charging and discharging of batteries, rotation of the solar arrays to maintain alignment with the sun, powering heaters to keep components from getting to cold, etc.
3) Course of Action (COA) Selection: Selecting the appropriate COA that a) minimizes the effects from the threat/hazard, b) maximizes attainment of mission requirements, and c) minimizes resource depletion. Requires multivariable optimization, in a noisy environment, with incomplete or missing information.
4) Mission Planning: Once a COA has been selected, developing the set of procedures required to execute that COA.

This topic is focused specifically on COA selection, although some work may be extensible to other areas.

To enable efficient and effective COA selection, AFRL is interested in the following (non-inclusive) technology areas:
1) Hypothesis development and rejection, to quickly populate, and then reduce, the set of likely anomalies and satisfactory responses.
2) Sensor or system tasking to generate, or gather, the most critical pieces of information that are currently lacking. Such taskings must also consider the temporal aspects of the information requirements.
3) Ensuring stability in under-defined and noisy mathematical systems.

Since the intent is to transition the technology into operational satellites, preference will be shown to those proposals that demonstrate traceability to the size, weight and power (SWAP) and computational limits of current and/or future space processing architectures.

PHASE I: Develop conceptual design of COA selection algorithms. Demonstrate how modules within the proposed decision making construct are able to efficiently handle data insufficiency. Demonstrate how differing system resource allocations can lead to different decisions. Identify key technical challenges, and additional effort required in Phase II.

PHASE II: Using the lessons learned from Phase I, design and fabricate a complete COA selection program clearly traceable to spacecraft integration; this includes development in an appropriate programming language. Demonstrate capability with datasets provided by AFRL.

PHASE III: Technology developed will be applicable to all military space platforms. Expected benefits include increased reliability and resilience in the face of natural hazards and man-made threats.

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KEYWORDS: autonomy, decision making, resiliency, insufficient information, resilient space systems

AF151-097 TITLE: Space Based Multi-Sensor Data Fusion to Quantify and Assess the Behavior of Earth-Orbiting Artificial Space Object Population

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Focusing specifically on sensors that could be placed on orbiting platforms, develop an information-driven method for maximizing the detectability and state assessment of other Earth-orbiting artificial space objects.

DESCRIPTION: The detectable population of Earth-orbiting artificial space objects is not rigorously nor comprehensively quantified. Some studies are available but their applicability and orbit regimes are typically limited. The manner in which data is collected contributes to or detracts from overall situational awareness. Current methods may only stare at a particular part of the orbit regime for a given time then postulate on the orbit population via uniform or other statistical distribution which could introduce characterization error if the fundamental motion of the objects is not appropriately considered.

This topic seeks to undertake this challenge of characterization the population of artificial space objects utilizing on-orbit sensing. However, there is a limit to the type and number of sensors that can be carried by an orbiting platform. Given this limitation, appropriately choosing particular on-orbit sensors and combinations thereof that deliver the most accurate and timely knowledge is required. With the chosen sensor suite(s), tasking algorithms are required to fully exploit the information offered by sensors operating in different modalities. It is important to demonstrate what could be achieved given the current state of space qualified sensors as well as demonstrate what level of characterization could be achieved via appropriate data fusion and sensor tasking strategies.

The fundamental requirement for this activity to be successful is to explore methods that maximize the probability of detection for resident space objects, which may or may not be hard to detect, as well as be able to revisit populations of interest for catalog maintenance. Multi-modal sensing is required as when the probability of detection in one frequency or wavelength may go to zero while it may go toward unity in another modality. Once detectability is maximized, the next area to pursue is what can be inferred from these sensor detections. Physical characteristics are commonly of interest (e.g., size, shape, materials, orbit, orientation, etc.) but even further, functional characteristics are of interest (e.g., mission, capabilities) so that situational awareness can be appropriately and reliably quantified. Observability analysis of object parameters and behavior is critical in providing realistic quantification of the object population and its behavior when outside of the field of view and should be rigorously assessed.

PHASE I: Identify possible sensors and combinations to be placed on orbiting platforms and derive the mathematical relationships between those sensors and space object parameters of interest to infer. Demonstrate current sensor capability and probability of detection maximization concepts using simulated data and key metrics for single and multiple sensors with the intent to exploit multi-modal sensing.

PHASE II: Develop/update the technology based on Phase I to provide a prototype demonstration of the technology in a relevant environment encompassing complex observations scenarios and using sensor data subject to error and bias as well as constraints on computational burden. The relevance of the environment will be dictated by the Air Force Research Laboratory and may fit in supporting various AFRL R&D programs and flight experiments.

PHASE III: Integrate algorithm enhancement technology into a Major Defense Acquisition Program (MDAP) program of record. Partnership with traditional DoD prime contractors is encouraged to facilitate successful transition and integration into an operational environment.

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KEYWORDS: multi-sensor, space, tracking, fusion, algorithm, taxonomy, situational awareness

AF151-098 TITLE: Automated Scaling Software for Oblique Incidence Ionograms

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop a real-time automatic scaling software system for oblique incidence ionograms (Oblique Ionogram Autoscaler, or OIA).

DESCRIPTION: The Air Force and other government agencies have Intelligence, Surveillance, and Reconnaissance (ISR) and Space Situational Awareness (SSA) requirements to specify the ionosphere on both a regional and global basis, in support of communications and surveillance systems that rely on, or are affected by, the ionosphere. The oblique incidence (OI) ionosonde is of great interest for monitoring and studying the ionosphere. With the ability to automatically process OI traces (and/or quasi-vertical, QVI) one transmitter can support a number of receiving stations, greatly expanding range and reducing cost per coverage area. Traditionally, ionograms were processed manually ("scaled") by a trained person with experience in interpreting ionograms. However, in today's world, manual scaling is no longer tenable except for special studies, and real-time automatic processing of the ionograms ("autoscaling") is mandatory; especially for operational systems.

The most modern assimilative ionospheric models can use OI data, but there is currently no good source of extracted trace data available. Multiple vertical incidence ionogram autoscaling systems have been developed in the past by different organizations, but we are unaware of any such well-developed system for OI. The purpose of this SBIR is to produce a first-generation OI autoscaling technology capable of delivering output, including quality control metrics, suitable for assimilation into ionospheric models.

PHASE I: This effort will review past work on OI autoscaling and develop algorithms capable of performing the autoscaling of OI traces. Data format information and requirements will be included. It is desired that the initial OIA capability be able to identify the OI traces and to separate the O and X echo traces even in the absence of polarization information. The OIA will be required to provide an estimate of the maximum frequency of the OI link.

PHASE II: A prototype OIA capable of extracting the full OI traces and able to recognize and scale all propagation modes present will be produced and tested in Phase II. The OIA must be tested against a set of oblique ionograms from various sources provided by AFRL/RVB. The product will be documented with an ICD. Phase II will further develop the ability of the OIA to estimate its level of success in the autoscaling of each ionogram in terms of the features that limit the validity of its autoscaled traces.

PHASE III DUAL USE APPLICATIONS: The OIA would be used by Air Force and other agencies to support ISR and SSA requirements, in particular the specification of the ionosphere below the height of the F2 peak for systems such as Over the Horizon Radar and surveillance systems that determine the location of an uncooperative HF emitter.

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KEYWORDS: oblique incidence ionosonde, ionogram autoscaling, ISR, SSA, sub-peak profiles, coordinate registration, geolocation

AF151-101 TITLE: Hardware-in-the-loop Celestial Navigation Test Bed

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop technologies leading to an advanced hardware-in-the-loop (HWIL) test and demonstration capability for integration of future miniature strap-down precision celestial navigation systems with guidance concepts for long-range platforms.

DESCRIPTION: Celestial navigation concepts are being developed to augment inertial navigation systems on long-range guidance systems. These systems sense airframe attitude, through measurement of the relative angular position of known celestial objects, and position, if a reference frame relative to the local horizontal can be inferred. Since these systems directly impact accuracy of closed-loop guidance, a capability to test them as an integral part of the guidance system, i.e., hardware-in-the-loop simulation, is desired. Development of advanced star trackers for use in manned aircraft, remotely piloted aircraft (RPAs) and weapons will require a hardware-in-the-loop capability to integrate, test, and calibrate the system on the ground. This technology could also be used to support commercial interests, such as testing trackers for use in commercial maritime, aviation, and space navigation applications.

A number of challenges exist that exceed the capability of current hardware-in-the-loop simulators. Optical representation of star maps with radiometric accuracy is required in the visible through the short wave infrared spectrum. Collimated representation of the star field is required to sub-microradian accuracy. These advancements will require innovative solutions to extend scene generation capabilities to shorter wavelengths with increased contrast (greater than 2000:1).

Capability is needed to represent the sky and stellar background including for a wide range of day and night celestial objects, backgrounds and optical distortions. Representation of atmospheric objects (clouds, aerosols, etc.) and scatter along with possible interference of earth/sea glint and earth limb must also be considered. It is also a goal to provide radiometrically adjustable targets. In other words, it would be nice to have the ability to accurately simulate star color in the scene generator.

These advancements will require innovative solutions to extend scene generation capabilities to shorter wavelengths with increased contrast (much greater than 2000:1), represent point source angular position to higher accuracy (about 100 urad) over a large field of view (greater than 20 degrees), and to represent a broad spectrum of airframe motion to navigation accuracy (greater than 400 deg/sec). Dynamic representation of stellar objects including Sun (V.M. -26), Moon, stars and space objects ranging from Magnitude 15 to Mag -4+ are needed. The need for objects with static magnitudes and temporally modulated magnitudes is also anticipated.

Innovative solutions are being sought that will allow the insertion of celestial navigation systems, including associated inertial measurement units, into a hardware-in-the-loop test environment. While complete solution concepts are strongly encouraged and will be given priority, partial capabilities that describe one or more of the identified challenges will also be considered. Anticipated solutions range from complete environmental simulation using hardware simulators, to full or partial digital injection capabilities if hardware solutions are unreasonable.

Dynamics of the platforms under consideration deviate in major ways from traditional stellar inertial instrument application for attitude control on stable satellite platforms. A star tracker for use in manned aircraft, RPAs and weapons will require a much more robust dynamic environment for targets and backgrounds due to the missile and aircraft high G dynamics and severe flight vibrations to be replicated during star tracker testing. Some instrument concepts under consideration require stimulation of the star field at up to 800 frames per seconds to reduce air frame vibration effects at high Mach number.

The approach should represent point source angular position to higher accuracy (less than 100 microradians) over a large field of view (greater than 20 degrees), and to represent a broad spectrum of airframe motion to navigation accuracy. Goals include to provide image motion rates of more than 400 deg/second in a random direction to represent actual flight dynamics of an airborne missile platform. The number and type of targets to be projected or simulated and the approach for quasistatic and dynamic stellar objects must be addressed to provide a representative number of objects in the stellar instrument field of view.

Other considerations include angular static accuracy measurement. Calibration of the instrument in a very high fidelity angular measurement system – something that is capable of calibrating to 5-10X better than what is required on the star tracker. Current test systems range from an angular accuracy of about 1 arcsecond to 20 milli-arc-seconds (100 nanoradians).

PHASE I: Investigate WFOV Vis-SWIR HWIL technologies that can potentially achieve 200 nanoradian or less accuracy for high speed strapdown star tracker HWIL. Address a wide range of day and night static and dynamic celestial objects, with backgrounds, atmospheric, and aerothermal optical distortions. Analyze and design a Phase II prototype compatible with a demonstration in the AFRL KHILS facility.

PHASE II: Develop and demonstrate in KHILS a high dynamics star tracker test bed prototype with real-time scene generation for HWIL of advanced strap-down stellar inertial navigation and position determination concept exploration. The concept should address: Vis-NIR-SWIR spectral bandwidth; high sampling rate star tracker sensors; Dome, Flight table and High Frequency Motion Table compatibility; and include earth limb, stars, sun, clouds, aero thermal effects, and resident space static/dynamic objects.

PHASE III: Transition to operational test sets for aircraft, missiles, and ground vehicles. Apply to advance space operations systems for preflight calibration and accuracy determination.

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KEYWORDS: star tracker testing, stellar inertial test bed, real time, HWIL, optical simulator, short wave IR, SWIR

AF151-102 TITLE: Novel Penetrator Cases for Explosive and Fuze Survivability

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop novel warhead cases that reduce adverse shock loading on the explosive and fuze during the penetration event without compromising the strength and lethality of a conventional unitary case design.

DESCRIPTION: Penetrating weapons experience tremendous shock loads on the explosive fills and fuze components. This problem is only expected to worsen as weapon velocities and strength of materials in targets increase.

One approach is to use an interior structure in the warhead cavity that would reduce movement and displacement in the explosive during penetration. There are two ways this might be implemented: (1) the explosive might fill an open cellular structure like a linear cellular array [Ref. 1] and/or an open cell foam [Ref. 2, 3], or (2) the explosive might be subdivided into discrete modules or compartmentalized by baffles or barriers. The intent in the first approach is to reduce explosive movement by increasing case-explosive bonding -- through increased surface area or increased bond interface strength, or both -- without creating friction that might generate hot spots and inadvertent ignition. The intent in the second approach is to manage axial movement of the explosive by distributing a portion of the loads radially rather than axially.

These cases might be all metal structures or composite structures made of multiple materials. Metal structures might be created by traditional machining processes, additive manufacturing processes [Ref. 4], advanced casting processes, or a combination of these methods. The cases might be monolithic or composed of multiple parts (e.g., a thin-walled case with liners or inserts).

These novel warhead cases should have mass-to-charge ratios that are equivalent to (or preferably, lower than) traditional unitary cases. Simply replacing explosive mass with additional (inert) structure is not a valid solution since this would have a negative effect on blast lethality. Structural energetic materials [Ref. 5] might be used in the interior structure to mitigate this effect.

The proposal should address scalability and affordability of the proposed concept given reasonable technology maturation and advances.

The approaches discussed above are not meant to constrain other innovative concepts. Alternate concepts are acceptable and welcome.

PHASE I: The contractor will develop the system concept or sub-system component through modeling, analysis, and breadboard development. Small-scale testing to show proof-of-concept is highly desirable. Merit and feasibility must be clearly demonstrated during this phase.

PHASE II: Develop, demonstrate, and validate the component technology in a prototype based on the modeling, concept development, and success criteria developed in Phase I. Deliverables are a prototype demonstration, experimental data, a model baselined with experimental data, and substantiating analyses.

PHASE III: The military application is ordnance for hard and deeply buried targets. Commercial application might include shock mitigation in automobile collisions and other impact events.

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KEYWORDS: warhead, explosive, fuze, survivability, ordnance, weapon, shock mitigation, penetrator, penetration, impact, structural energetics, rapid prototyping, additive manufacturing, Direct Metal Laser Sintering, DMLS, composites

AF151-103 TITLE: Shock Hardened Laser Targeting System

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a shock-hardened laser target designator and 40 mm precision guided laser weapon for close air support and close quarters combat.

DESCRIPTION: To develop a miniature semi-active laser (SAL) seeker /spot tracker sensor compatible with small lethal unmanned air systems (UAS) and miniature munitions that avoids substantive blocking of the low-yield munitions effects.

The use of small armed UAS and precision guided munitions (PGM) for close air support requires that the PGM be guided to targets with extreme accuracy. These low yield miniature munitions provide the option for localized targeting with minimal collateral damage. To allow for an efficient PGM, volume and weight of the guidance system must be minimized.

Miniature PGMs require guidance systems that scale with the size of the munition. Many tactical systems already employ SAL seeker guidance. Current SAL sensor modules are typically larger than the miniature munition itself (40mm diameter). A particular application in mind is a laser guided rocket propelled grenade launched from a small UAS (SUAS) or a standard M16 grenade launcher.

A need exists for a fundamentally simple seeker sensor implementation, based on modern, low-cost, low-noise micro-electronics. To be effective on a micro-air weapon, such a guidance system should occupy less than a couple cubic inches, be able to acquire the designated target at ranges of >1 km, and provide 2D directional processed error-signal feedback to the guidance system at a >25 Hz update rate.

There is also a need to develop and demonstrate a shock hardened laser designator that meets current STANAG requirements for direct fire laser target guidance for use with rail mounted aircraft and hand-mounted weapons at target engagement ranges up to 3 km.

Additionally, the sensor must be small enough as to not interfere with the forward placement of the low-yield explosive effects. The sensor must address compatibilities with current NATO approved modes and wavelengths and address future high pulse code rate advanced coding schemes which may include bursts of meta-data embedded in the pulse train. In addition the sensor must be compatible with future eye-safe wavelengths.

PHASE I: Develop a proof of concept approach for a miniature compact SAL seeker/spot tracker and shock hardened weapon mounted target marker. A critical demonstration experiment with components in a laboratory environment is desired. Address the hardware robustness and the cost scaling and form-factor required for a deployed system. Address field of view needed for laser spot application.

PHASE II: Further refine the approach and build and demonstrate prototype form-factored micro- seeker/sensors integrated with flight systems and tested with a variety of semi-active lasers. Show that the prototypes meet the requirements for the system performance of a small UAS body centered or turreted sensor integrated or in a gimbaled/strapdown seeker mode for small (<40mm sized) munitions.

PHASE III: Transition for Air Force Special Operations Command and other hand- and air-launched applications.

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KEYWORDS: laser guided projectile, 37mm grenade, CAR-4, laser designator, direct fire, semi-active laser

AF151-104 TITLE: Rigid-body Off-axis Ordnance Shock/Tail-slap Environment Replicator (ROOSTER)

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual

use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a low-cost, reusable, pseudo-static testing technique capable of imposing high acceleration and deceleration (> ±10,000 g), opposing loads to a large (10-100+ lbs) payload that are sustained over long durations (>5 ms).

DESCRIPTION: Weapons undergo long duration, high amplitude, multiaxial decelerations during the penetration of targets. This imparts momentum on the entire weapon system which is correspondingly reduced due to the penetration resistance of the target. Even for the rigid body (i.e., ignoring flexible body dynamics), the inertial deceleration forces can exceed 10,000 g"s (gravitational acceleration) and remain above that threshold over a long duration, often well in excess of 5 ms. Adding to the harshness of the environment is the multiaxial nature of the loading, which includes both bending and shear moments. The most extreme example is in "tail slap," where large lateral accelerations are introduced due to the bending and rebound of the weapon in the lateral direction (i.e., perpendicular to the axis of penetration). Developing a controllable test method and predictive capability to apply this environment in testing is critical to the development of fuze, energetic, and other weapon technologies. However, the corresponding change in velocity typically requires ballistic or operational testing. Both testing methods are extremely costly, personnel intensive, and introduce both technical and safety risks. It is therefore desirable to develop a low-cost, reusable testing method (and accompanying experimental and simulation capabilities) that can reproduce acceleration/time profiles representative of penetration (amplitude for a duration, or equivalently the integrated velocity change) in opposing (shock-countershock) and multiple directions (multiaxial) for a sizable test article (threshold 10 lbs., objective 250 lbs.).

Practical test considerations also impose additional requirements beyond the required multiaxial acceleration/duration performance. Most tests call for more sensor channels than are recordable in an onboard recording system. In these instances, a nearly-stationary (i.e., “pseudo-static”) test article is typically used. An additional benefit is that off-board instrumentation is able to collect more channels of data with higher precision and sampling rates. One example of a pseudo-static testing is reverse ballistics where a target is propelled into a stationary UUT. Finally, a scalable solution will enable testing of both small UUTs and larger test vehicles, with an objective of testing large size (>6 in. diameter) subscale weapons (with weights approaching 250 lbs.).

The ability to accurately model both the test conditions and the test article is critical to a successful effort. A virtual model of the system should be built as part of the development and subsequently used for predictive analysis. The model will be used for designing experiments to tune experiments to minimize the number of tests needed to accomplish the objectives. A validated model will also have enduring benefit for evaluating the survivability of candidate weapon technologies (e.g., fuze electronics) in this extremely harsh environment.

The technical effort (both experimental and computational) will focus on a non-inventory subscale warhead to demonstrate the viability of the approach and maximize its utility in early weapon system research and development. The government will provide the design details for the subscale system, including drawings of the system as well as the available material properties, as GFI in this effort. Operation and demonstration of the system at government test facilities may also be required due to security considerations.

PHASE I: Model candidate technologies. Evaluate time/acceleration performance in a uniaxial and multiaxial configurations as measured using external and embedded senors. Identify design parameters and perform scalability analysis. Perform proof-of-concept assessment and/or testing on key component technologies.

PHASE II: Integrate component technologies and assemble prototype test apparatus. Perform pretest safety and performance analysis. Experimentally demonstrate uniaxial and multiaxial performance that meets technical objectives. Validate system model.

PHASE III: Mature & commercialize test capability for both military and civilian uses. Dual-use applications include hazardous material transport testing, automotive and aerospace crash testing, and unmanned space operations.

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3. Military Handbook of Fuzes, MIL-HDBK-757(AR), 15 April 1994. (Public Releasable via USA Information Systems, Inc; www.usainfo.com, 757-491-7525).

KEYWORDS: fuzes, energetics, explosives, shock testing, hard target fuzes, harsh environment, acceleration, fuze testing, multiaxial loading

AF151-105 TITLE: RF Seeker Performance Improvement in Difficult Environments through Circular Polarization

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Research and develop a circularly polarized high-gain, high bandwidth Ka band radar seeker antenna.

DESCRIPTION: Current and future military operations include difficult environments such as high clutter environments and heavy rain and require improved levels of weapon seeker performance. Small and agile munitions require precision guidance capability to maneuver in obstruction-rich and highly cluttered urban, suburban, foliage rich and mountainous environments to engage mobile targets. The loss/degradation of GPS and communications encountered in military operations and intermittent line-of-sight to the target add additional seeker system challenges. Precision guidance is tightly coupled to lethality in that small weapons must achieve a small Circular Area Probability (CEP) to accommodate small warheads, while maintaining a high probability of kill (Pk).

Hence the weapon seeker needs to have a Ka band RF seeker that has added discrimination to enable performance in challenging environments to include attenuation due to rain. The purpose of the SBIR topic is to investigate and develop small circularly polarized or multi-polarized Ka band antenna technology, with a gain greater than 27 dbi, a band-width up to 1.2 Ghz and main lobe of 7 degrees. The preference is a conformal antenna however is not mandatory for this effort, and should be implementable in a sum and difference mono pulse configuration in Phase II or III. The antenna should have the smallest form factor possible with uniform illumination, should not exceed a 6 inch diameter and size, weight, power and cost (SWAP-C) should be minimized.

PHASE I: Analysis is accomplished to identify innovative Ka band antenna technologies that will provide seeker discrimination capability through circularly polarized sensing. Candidate designs should be developed for performance on a modeled airframe based on electromagnetic simulation, and have at least 27 dbi of gain, a band-width up to 1.2 Ghz and a main lobe less than 7 degrees.

PHASE II: Produce antenna and prototype designs of a multi-polarized Ka band, high-gain, high band-width seeker antenna. The antenna candidates shall be fabricated and tested in the far field, and compared to modeled results, resulting in model refinement and validation. An optimum antenna then needs to be chosen from the candidate designs, tested on a small weapon like airframe in an anechoic chamber or with near field measurements transformed to the far field, for performance to include polar plots.

PHASE III: Commercial Application: Surveillance activities in law enforcement, search and rescue, border control, homeland security.

REFERENCES:
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KEYWORDS: high gain circularly polarized Ka band antenna, high gain circularly and linearly polarized Ka band antenna, wide-band multi-pole Ka band antenna with high gain

AF151-106 TITLE: Develop Advanced Cumulative Damage Models for Multi-Strike RC Bunkers

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop advanced cumulative-damage models that predict time dependent reinforced concrete (RC)-Bunker wall deflection, spalling, breach, secondary debris generation, and the incremental wall damage state from multiple weapon detonations.

DESCRIPTION: Future hard-target munitions will be used in cooperative ways and will require multi-strike tactics to functionally or structurally defeat hard targets, such as RC bunkers. The current Air Force Modular Effectiveness Vulnerability Assessment (MEVA) tool implements wall damage response in a limited parameter space (unrealistic room configurations and low RC compressive strength) and provides simple metrics (no prediction of spall, breach, or secondary debris) related to global wall response for first generation computational damage approaches developed for single and multiple weapon internal detonation events that predict local response of wall materials to blast and fragments. An assortment of numerical modeling techniques have been explored and considered to characterize continuum-level damage. Innovative second-generation cumulative-damage models are now needed that can consider multi-event or multi-insult detonations in a manner that builds on current RC-damage modeling approaches. Such approaches will provide analytical data for more rigorous engineering models that can provide more detailed local and global response modes that include time dependent wall deflection, spalling, breach, secondary debris generation, and incremental wall damage state from multiple weapon detonations. These damage parameters will be needed by progressive damage models whose requirements need to be included in this effort. A final objective is to utilize the cumulative damage data sets to develop efficient engineering approximations that can be run rapidly (milliseconds to seconds) in weapon effectiveness modeling tools such as the MEVA tool. If the engineering model(s) are not run efficiently, they may be poor candidates as prediction capabilities expand to consider progressive damage and/or collapse of complex target structures. It is in the best interest of the joint weaponeering community for the engineering model of cumulative damage (multi-weapon detonation damage prediction within a complex bunker) to be seamlessly compatible with MEVA data formats. For example, DLL models are one example of a consistent data structure with MEVA.

The requirement is for the development of models that predict the specified structural damage to hardened RC-Bunker structures subjected to multiple weapon detonations and have an overall accuracy of 80 percent or better when compared to actual test data. Blast & fragment loads from current & future penetrator weapons will produce the required loads. Quantification of modeling uncertainty and a representation of the models' predictive accuracy based on that uncertainty [1, 2] is required. This should include cumulative damage uncertainty.

The response of the models should address both air-backed and soil-backed walls, roofs and floors, including soil-structure interaction effects. In addition, the models should be able to handle the different room & hallway configurations typically found in bunkers (realistic bunker layouts). The resulting models will need to be integrated into the Air Force Research Laboratory (AFRL) MEVA architecture and have execution times similar to current models. The bunker structural configuration and the loads acting on the structural components will be provided as inputs from MEVA. In addition, the contractor should propose a limited set of test experiments that he can perform to validate his algorithms. If necessary, government test facilities and or test data will be provided if requested and within the government's funding constraints. If required, government HPC facilities will be provided to the contractor upon request.

PHASE I: Demonstrate the feasibility of developing innovative high-fidelity physics-based (HFPB) simulations and engineering methodologies needed to simulate the effects of multiple weapon strikes in the rooms of realistic hardened RC-Bunkers and capture the important characteristics of the problem as specified.

PHASE II: Develop fast-running engineering-models that simulate the effects of multiple weapon detonations on the structural components of realistic hardened RC-Bunker structures. Capture the important characteristics of the problem for the desired input & output parameter space. Validate the HFPB models with experimental data and quantify the accuracy of the engineering models. Implement the engineering models in AFRL's MEVA and standalone codes, and support code verification efforts.

PHASE III: Military application: Continue the development of these models for any additional weapons, structural components, and/or materials required. Adapt the engineering models developed in Phase II for use by other government agencies.

REFERENCES:
1. Wathugala, G.W. and T.K. Hasselman, "ARCWALL-LP: Load Parameter Based Fast Running Model For Predicting Reinforced Concrete Wall Response To Cased Weapons," Proceedings of the SAVIAC 77, Monterey, CA, October 2006.

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3. Crawford, J.E., and H.J. Choi, "Development of Methods and Tools Pertaining to Reducing the Risks of Building Collapse," Proceedings of the International Workshop on Structures Response to Impact and Blast, November 2009, Haifa, Israel.

KEYWORDS: structural response, MOUT, urban targets, weapon lethality, finite-element models, bunkers, cumulative structural damage, progressive damage

AF151-107 TITLE: <u>Long-Range Adaptive Active Sensor</u>

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: The objective of this research and development effort is to develop and demonstrate compact aperture ladar technologies that may provide long-range (100s to 1000s of km) detection of theater ballistic missiles and other fast targets.

DESCRIPTION: Advanced laser radar (ladar) technology promises to contribute significantly to detect, track, identify and kill the ballistic missile. Innovative methods used to improve ranging laser transmitters and receivers are required to enable precision tracking and discrimination of threatening targets at long ranges (100s to 1000s of kilometers) while simultaneously reducing size, weight and power (SWaP) are critical to the future success of fielded active interceptor seekers.

In traditional systems, only the power, pulse-width, and repetition rate were controllable variables that limited the performance.

In recent years a number of alternative approaches enabled by laser and electronics technology advances have been investigated. Consequently, it is now possible to add further dimensions to laser radar sensing.

By varying the characteristics of the transmitted waveform and concomitantly adapting receiver designs it is possible to increase resolution, detection ranges, and size, weight and power performance. This topic is focused on the adaptation of such technologies in detection such as the low probability of intercept ballistic missiles.

For use on tactical aircraft or Air Force RPA platforms, minimal transmitter and receiver aperture sizes preclude many traditional ladar angle range detection techniques. This investigation is to determine the suitability of using advanced telemetry components modified to achieve long-range diffraction limited imaging and meter or less range accuracies and velocities without large meter class apertures for long range targets.

PHASE I: Analyze proposed laser technologies and applications for performance improvement. Evaluate initial packaging issues and technology capability. Laboratory demonstrations of candidate technologies would be considered a plus. Address component maturity, power, pointing accuracy, and signal processing to augment current Air Force targeting pods and sensor balls.

PHASE II: Demonstrate engineering prototype of proposed technology, identify and address technological hurdles and provide a prototype demonstration. Demonstrate applicability to the ballistic missile detection problem through hardware in the loop, open air range testing and other opportunities.

PHASE III: Engineering and development, test and evaluation, and hardware qualification of the proposed technology applications to military long range target ID, clear air turbulences/wake detection, meterological and geodetic applications, maritime navigation. and commercial airspace collision avoidance.

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KEYWORDS: Laser, laser ranging, LADAR, missile defense, airborne

AF151-108 TITLE: Advanced Multisensor Concepts for Theater Ballistic Missile (TBM) Interceptors

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop methodologies/algorithms utilizing active/passive (IR/RF/etc.) sensor track data to classify TBM targets, predict final impact coordinates in order to prioritize engagement, and to predict TBM trajectory to enable intercept.

DESCRIPTION: With the proliferation of short, intermediate, and long-range ballistic missiles (SRBM, IRBM and LRBM), protecting our forward operating bases (FOBs) is becoming a growing concern for our Regional and Theater Commanders. Our current land- and sea-based counter ballistic missile systems are not plentiful or mobile enough to adequately protect all our FOBs. To complement our current capabilities, an airborne weapon layer is being investigated. As part of this effort, an assessment of the ability to rapidly identify the threat missile class (SRBM, IRBM, LRBM or SAM) and predict its final impact coordinates to support engagement prioritization and to optimize intercept probability is critical. This SBIR requires the identification of a host platform(s) multi-mode sensor suite (MMW radar, imaging IR sensors, etc.) and munition seeker to develop classification and trajectory algorithms that can be used to successfully intercept a TBM or SAM (surface-to-air missile) in flight. A stretch goal would be to assess the benefits of integrating additional Missile Defense Agency sensor elements (TBM architecture) to rapidly and accurately support the engagement of in-flight threat missiles.

PHASE I: Research detection, acquisition, track, classification, identification, discrimination, and terminal guidance algorithms and processing for long range air launched weapons. Address standoff engagement of boosting targets. Include inertial requirements, target state data, and in-flight update requirements as necessary. Show by simulation, the design addresses current and projected threats.

PHASE II: Through simulated and HWIL (hardware in the loop) data with surrogate sensors, develop processing to demonstrate launch to impact (hit to kill) flyout. With simulations and/or captive carry show the multi-sensor processing can address natural and deliberate degraded situations including cloud break, atmospheric effects, countermeasures, maneuvers, staging, and non-nominal events. Develop and demonstrate a processor testbed that can integrate prototype seekers and processors.

PHASE III: Develop and transition a real-time multi-sensor/seeker processor for use in captive carry and HWIL evaluation of novel sensors and seeker to support long range missile engagement of ballistic missiles and multiple role other targets.

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KEYWORDS: ballistic, prediction, intercept, guidance, HWIL, algorithms, data fusion, Hercules, test bed

AF151-109 TITLE: Hostile Fire Detection and Neutralization

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop an airborne sensor capability to rapidly detect and neutralize ground-based weapons. Threats include both optically and non-optically sighted systems.

DESCRIPTION: Ground-based kinetic weapons pose spontaneous and unpredictable threats to aircraft. They may be optically (lens) equipped/assisted or man-guided.

These weapons must be detected within 360 degrees of the aircraft using existing onboard aircraft EO/IR sensor systems. Light weight, low cost, small form factor, minimum power solutions are needed that may be integrated with existing aircraft systems to minimize impacts to current aircraft configurations.

Precision location of threats is required in order to effect neutralization through onboard countermeasures. The sensor system will have the ability to detect muzzle flash and rapidly provide geo-location, allowing the non-lethal neutralization of the threat. Additionally the system will have the ability to actively detect optically sighted systems, geo-locate, and provide a non-lethal countermeasure prior to the weapon being fired. Threat geo-location and direction of fire solely for the purpose of evasion are not of interest. The system should be able to detect and neutralize multiple threats simultaneously. The sensor is desired to be able to detect and discriminate small arms fire at altitudes up to and beyond 10000 feet. It is desired that the sensor system be able to detect and discriminate larger munitions such as rocket-propelled grenades (RPGs), mortars, AAA (anti-aircraft guns), and surface-to-air missiles (SAM) at altitudes up to 35000 feet. It is highly desirable that the system provide non-imaging and imaging levels of capability with non-cryogenically sensor systems. There are currently no non-cryogenic, low-cost hostile fire systems which are successfully fielded for this effort.

Previous sensor have been developed and tested for lower altitude unmanned air systems (UAS) but are large, expensive and lower sensitivity than needed for high altitude UAS operation. Previous approaches have also been subject to glint false alarms and unable to accurately discriminate type of event or friendly vs enemy fire. Basic sensing technologies and signal processing algorithms and subsystems have reduced size, weight, and power (SWaP) required for a hostile fire detection sensor to within the capabilities of many current and near-term remotely piloted aircraft (RPA) platforms to perform this mission. RPAs are becoming the primary platforms for persistent battlefield surveillance and the requirement for extended time on station determines to a great extent the available weight allocation for any hostile fire sensor system. Future RPA hostile fire sensors systems will take the form of Line Replaceable Units for legacy sensor payloads currently in use on the RPA fleet. Therefore, the size, weight, and power consumption of hostile fire sensor systems must emulate that of previous generation sensor systems without hostile fire sensing capabilities. Sensor system and processor must operate with minimal operator interaction. System must be light weight, low drag, and suitable for CV-22 helicopter, MQ1/9 and C-130 flight environments.

The hostile fire sensor system must demonstrate the capability to operate with both low false alarm rates and relatively high probability of detection under operational conditions. The additional capability to perform threat geolocation in support of not only direct attack, but indirect attack, necessitate a close coupling between the sensor system and some form of inertial measurement capability either integral to the sensor or available as part of the mission flight package for the aerial platform. Determine the feasibility of meeting various sensor performance metrics using trade-space analysis from sensor component characteristics and available field measurements of weapon signatures.

The determination of military utility of a hostile fire sensor will be heavily dependent on its capacity to distinguish between friendly and hostile fire in order to avoid fratricide. There are different levels of fidelity currently defined for hostile fire sensor systems. Most systems currently differentiate among weapon classes, but lack a significant capability to confidently declare a weapon type within a class.
The goal is to design a sensor system prototype system to be integrated onto a test platform for the purpose of verification of sensor capabilities under live fire test conditions. Perform modeling and analysis to show the efficacy of the approach for different classes of threat systems. The Phase I prototype design will, potentially be heavier and less capable than an operational sensor, but the design should address traceability between demonstrable SWaP and performance for the captive carry prototype and an ultimate operational configuration for the hostile fire sensor. In the Phase I it is necessary desirable to demonstrate of the critical system technology components in a laboratory or field setting. In Phase II, develop and demonstrate the prototype sensor system to support a wide field of view, live fire tower and flight test under benign battlefield conditions.

PHASE I: Design a sensor/countermeasure system for detection and neutralization. Develop and demonstrate the critical component technologies for a low-cost hostile fire system.

PHASE II: Construct, integrate and demonstrate a prototype detection and neutralization system in live-fire testing. Develop and demonstrate the prototype hostile fire RPA sensor system to support a live fire flight test. Demonstrate the technology can provide greater than 99 percent false alarm rejection rate and greater than 95 percent detection rate for urban and battlefield small arms and large arms settings.

PHASE III: This technology would support military aircraft. Demonstrate through live fire sponsored exercises the operational utility of the detection and cueing capability. Military: Adapt the Phase II operational prototype for forward and airbase security applications.

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KEYWORDS: hostile fire detection, sensors, countermeasures, optical, neutralization

AF151-110 TITLE: Combined Multiple Classification Methods Using Machine Learning Techniques to Develop VIS-N-IR Spectral Processing

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a computer-based routine to process spectroscopic information collected by onboard optical systems to identify atomic and molecular features in the ultraviolet/visible/near-infrared (UV/VIS/NIR) region of the electromagnetic spectrum.

DESCRIPTION: Each formulation of energetic materials is unique and emits electromagnetic radiation that contains information pertaining to the chemical reactions and products generated during deflagration or detonation. While the late-time (about 1 ms) species emissions are well-characterized, the early-time chemical cascade (about 1 μs) is poorly understood. Spectral feature identification and source characterization in the field is arduous due to a lack of algorithms and software that can process such data in real time. Much of the current data regarding spectroscopic features is located in texts containing information on isolated species in a laboratory environment and is often over 30 years old. The desired program will identify field-collected emission signature data and characterize its source in real time.

There are currently multiple approaches of developing such processing programs, but they are generally implemented in remote sensing, land cover classification, and protein database applications. There is a critical need for a multivariate analysis method combining various approaches such as artificial neural networks (ANN) and support vector machines (SVM) to provide advanced feature extraction (FE) and learning capabilities to process the spectral information contained within the pixels of a UV/VIS/NIR spectral image. Santos et al. [Ref. 1] combined three feature representations and two learning algorithms (SVM and multilayer perception neural networks) to interpret hyperspectral data. A multivariate analytical program developed by Cerqueira et al. [Ref. 2] has utilized a database search algorithm to achieve a machine-learning technique for identification of proteins in complex mixtures. A third viable approach was implemented by Hsu and Yang [Ref. 3] that combines the advantages of ANN's with wavelet-based feature extraction wavelet network (WN) methods for data identification and classification. This topic seeks technical advancement through combination of identification and learning algorithms with real-time database construction and source characterization.

The intent of this topic is to develop appropriate algorithms and software to extract spectroscopic peak locations along a wavelength scale and identify unique features in the UV/VIS/NIR with intensity above that of signal noise and background continuum emission. The identified peak features will then be used to train an appropriate network learning algorithm to identify emission features in order to facilitate development of a database of UV/VIS/NIR spectral features characterizing chemical species found in early-time deflagration/detonation events of energetic and reactive materials. Collected data can have multiple file formats (e.g. ascii, pst, pfn) and are often converted to JCAMP-DX or FITS files in order to participate in international spectral library building efforts. Phase I of this effort will focus on files converted to ASCII format.

PHASE I: The contractor will develop the necessary system concept or system component through modeling, analysis, and breadboard development. Existing UV/VIS/NIR spectra of representative energetic materials will be provided by the program manager to allow proof-of-concept demonstration. Merit and feasibility must be clearly demonstrated during this phase.

PHASE II: Develop, demonstrate, and validate the component technology in a prototype based on the modeling, concept development, and success criteria outlined in Phase I. Deliverables are a prototype demonstration, experimental data, a model baselined with experimental data, and substantiating analysis.

PHASE III: The military application is rapid/reliable identification of reactive material chemical signatures from deflagrations/explosions. Commercial applications include use by law enforcement units, first responders, or agencies that have a need to quickly assess components of a fire or explosion event.

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KEYWORDS: artificial neural networks, data mining, feature extraction, feedforward systems, hyperspectral imaging, image classification, multi-layer neural network, neural networks, support vector machines, wavelet networks

AF151-111 TITLE: Campaign-Level Optimized Strike Planner

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Research and develop an air strike planning methodology/algorithm developed and integrated into the Theater Operations Research Model (STORM) that optimizes the assignment of air packages to targets based on a multi-criteria utility value function.

DESCRIPTION: Background. Historically, multi-criteria utility value function analyses have been accomplished through an analytic process where independent "cost" and "effectiveness" analyses are conducted and the results combined to provide some level of "cost-effectiveness" insights. The Combat Forces Assessment Model (CFAM) and STORM are two examples of useful analytic tools built for specific purposes. CFAM's optimization problem can be formulated with alternative objective functions and constraint sets, but a typical problem is to determine the mix of munitions required to maximize the value of targets destroyed given a set of prioritized targets (by distance band and time phase) while minimizing the cost (munition and aircraft losses) of the campaign. Although CFAM has been successfully applied to the Air Force's Nonnuclear Consumables Annual Analysis (NCAA) process, it has several limitations: it is a one-sided, air-only linear formulation of the cost optimization problem; the set of prioritized targets (often generated from STORM-based campaign analysis outcomes) must be provided as input; and it does not directly represent the effect of ISR on the air planning and execution processes. CFAM does not explicitly consider the operational context nor represent the inherent risk associated with countering an adaptive adversary's forces, capabilities and actions, thus limiting the cost-effectiveness insights available from the tool.

On the other end of the cost-effectiveness analytic question continuum is STORM, a campaign-level, perception-based analytic tool used by the U.S Air Force and Joint analytic communities. STORM explicitly represents U.S. and enemy air, space, ground and naval weapons, platforms and entities; and is used to provide effectiveness insights on the contribution of their combat and support capabilities to the campaign outcome, for both U.S. and adversary forces. The planning and execution processes dynamically react as the campaign unfolds with campaign, perception-based results (e.g., AAR support missions canceled, strike aircraft killed in the air or on the ground, air defense sites survive the A2S attack, etc.). STORM's air planning processes interact with, affect, and are affected by other warfare functionality areas (logistics, mobility, communications, ISR/sensors, etc.), and any modifications to the air strike planning process would need to account for those relationships and dependencies. Similarly, STORM's planning processes were designed with no consideration of cost in either the value functions or input data driving the process outcomes. This can best be illustrated by discussing the current air strike planning process. The user provides as input a prioritized target set as well as available air-to-surface munitions based on scenario requirements and National Command Authority/COCOM priorities. Given air asset and air-to-surface munition availability, STORM's air strike planning process uses a target-centric, greedy heuristic to select aircraft and weapons to strike the highest priority target (representing the warfighter's strategic intent) as soon as possible, considering only if the squadron (aircraft, munition with the highest expected yield) can satisfy the target's damage requirements (with no consideration of the munition/fuel costs or the cost of expected aircraft losses).

Bottom-line. This SBIR is to determine if the two aspects of a cost-informed operational effectiveness weapons analysis, previously handled separately as part of an analytic process, can be incorporated into a single tool to generate benefit-effectiveness insights that inform both the warfighters' and acquirers' decision space.

PHASE I:
1. R&D a utility value objective function and associated use case to illustrate its applicability to analysis challenges.
2. Identify algorithmic approaches and implementation strategies to efficiently solve the utility value function- and effectiveness-optimized air strike planning problem formulation.
3. Develop an optimized air strike planning model design and specification plan.

PHASE II:
1. Full development and testing of the optimized air strike planning model in STORM.

2. Conduct a delta study examining the operational effectiveness and performance differences between the "effectiveness-only" and implemented "utility value function and effectiveness focused" air strike planning processes.
3. If appropriate, produce cost-effectiveness analytic insights in support of an Air Force Research Laboratory weapons program.

PHASE III: The earlier OSD criterion required examples of military AND commercial applications. The current criterion now requires only one application: military, commercial, or both.This strike planner in STORM model would have extensive potential for use by the DoD in AoAs and other evaluations.

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KEYWORDS: campaign, STORM, planner, optimizer

AF151-112 TITLE: Next-Generation Semi-Active Laser (Next Gen SAL)

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop next-generation Semi-Active Laser (Next Gen SAL) seeker technologies (designators, optics or detectors). Technologies shall provide improved man-in-the-loop designation with enhanced end-game aimpoint selection on stationary/moving targets.

DESCRIPTION: Current SAL designator/optics/detector technologies have been matured with marginal gains for many decades. Budget constraints and backward compatibility requirements to currently fielded systems (designators and weapons) have limited conceptual development. Though backward compatibility should be a consideration, this topic seeks to remove the hard compatibility requirement to see if significant gains can be made in acquisition range, sensor performance and end-game aimpoint selection. Technologies to be investigated include designators, optics and detectors. Proposals may focus on one or all technology areas. Designators may be ground based or airborne. New designator concepts should explore the laser wavelength (the traditional 1.06/1.55 microns and others), pulse repetition frequency (10Hz to 10s of kilohertz), pulse widths and methods of lasing the target (stationary or optimized scan patterns). Optical considerations should include: 1) field of regard/view (30 degrees or greater is desired); 2) gimbal/non-gimbaled systems (traditional gimbals are discouraged due to size, weight and power; we prefer wide field of view (WFOV) optics or MEMs based optical steering); 3) optical throughput, 4) solar rejection (tracking targets in the presence of a bright background source, i.e., the sun) located at any field point greater than 2 degrees (threshold), 1 degree (objective) from the intended source; and 5) narrow band-pass filtering of the source to a 10nm (threshold), 2nm (objective) transmission bandwidth, which shall be effective throughout the entire field of regard of the seeker. Detector concepts should focus on target acquisition (>7 km with a 50 percent reflective target) and end-game aimpoint selection. The concepts may include traditional quad cells, imaging or some combination of the two. Detector performance should include the trade space of the designator concepts above and be able to respond to PRFs, pulse widths and scan patterns appropriately to improve aimpoint selection. Detector responsivity for low reflective targets and overall detector dynamic range will be key considerations. Seeker diameters are 5 inches for a threshold and 2.75 inches for the objective. Cost should be a consideration, but not a key driver at this point. Given the inventory of SAL designators and weapons currently being fielded, it is desirable to focus first on optics/detectors for performance improvements and designators if required.

PHASE I: Design innovative Next Gen SAL seeker sub-system concepts (designators/optics/detectors) for development and testing. Conceptual designs shall be analyzed/modeled both optically and radiometrically to identify the performance and limitations of the technologies. Identify any assumptions or requirements regarding sensor/detector configuration or any additional optics required for operation.

PHASE II: Produce a system design and prototype of the Phase I concepts. Prototypes will be laboratory and field tested at Air Force Research Laboratory. Analysis and models shall be updated to reflect design improvement or changes from Phase I. ROM cost estimates will be created.

PHASE III: Development of the technologies described above will have immediate application to laser communications in both military and commercial sectors. The technology should find ready applications in laboratory applications.

REFERENCES:
1. Patent US 7,587,109 B1, “Hybrid Fiber Coupled Artificial Compound Eye,” Spectral Imaging Laboratory, Francis Mark Reininger, Sep. 8, 2009.

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3. J. English, R. White, "Semi-active laser (SAL) last pulse logic infrared imaging seeker," Proceedings of the SPIE Volume 4372 (2001).

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KEYWORDS: semi-active laser guidance, human-in-the-loop, autonomous guidance and control, wide field-of-view, laser designated, WVOV, Next Gen SAL

AF151-113 TITLE: <u>Miniaturization of RF Seekers</u>

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: The overall objective is to optimize and minimize the cost, size, weight and power (CSWaP) of RF seekers. A full system study should be performed to determine the trade-off between CSWaP reduction and any corresponding decrease in performance.

DESCRIPTION: Next-generation fighter aircraft will have a limited number of internal weapons bays, each having CSWaP constraints. This directly impacts the size and number of air-to-ground weapons that can be carried per mission. Therefore it is highly desirable to minimize the CSWaP and maximize the munition loadout to increase sortie effectiveness. This drives weapon designers to develop smaller munitions, such as Small Diameter Bomb (SDB) and Small Diameter Bomb Increment II (SDB-II), which in turn drives an increase in the accuracy requirements and minimization of Circular Error Probable miss distance to maintain the intended weapon effectiveness. Since these munitions will be used in highly contested air spaces, systems are expected to be lost through attrition. This loss also drives the need to maximize loadout, to insure a sufficient number of weapons reach their desired target. With this increased number of weapons to be released, the per unit cost must be minimized. The challenge is to develop low cost and compact RF seekers. This could be done by studying more efficient RF architectures and components and/or smaller more efficient apertures. The CSWaP goal for this study includes a per unit cost of less than $15K, a maximum size of a 6” diameter by 6” long cylinder (170 cubic inches), weight less than 10 pounds, and a maximum input power of 100 W.

PHASE I: The Phase I effort should study the main drivers of CSWaP for current RF seeker technology. Once the main drivers are determined, the study will focus on innovative technologies to reduce the CSWaP. Trade-offs will be conducted to determine the optimal solution for CSWaP reduction with respect to RF seeker performance.

PHASE II: The Phase II program will concentrate on the development and demonstration of the selected component and system technologies determined by the Phase I study. The goal is to demonstrate the performance of the components with the reduced CSWaP, and to further mature the technologies

PHASE III: The Phase III program will build a prototype miniature RF system and demonstrate performance with reduced CSWaP.

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1. Skolnik, M.I., Introduction to Radar Systems, 1980: McGraw-Hill Publishing Company.

2. Eaves, J.L. and Reedy, I.K., Principles of Modern Radar, 1987: Van Nostrand Reinhold.

3. Goldberg, I.G., "Linear Frequency Modulation Theory and Practice," RF design, 1993.

KEYWORDS: RF Seeker, MMW, radar

AF151-114 TITLE: Dynamic Characterization Methods for Composite Materials Systems

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: The objective of this work is to develop experimental methods and measurements for safely and accurately extracting fundamental material properties from as manufactured reactive material components.

DESCRIPTION: Weaponization of current and future air platforms will require smaller munitions with equivalent or better lethality when compared with today’s weaponry. Structural reactive materials (SRM) provide both strength and energy release and can be used to enhance warhead lethality over traditional metallic warheads. Unlike conventional steel warheads, the lethality of SRMs is due primarily to the combustion of small particles and therefore requires an understanding of how to control the distribution of fragmentation to achieve the desired terminal effects. These materials will likely have highly anisotropic mechanical and reactive properties and have fragmentation behaviors quite different than traditional materials.

Composite structures utilize manufacturing methods that produce final parts with geometries and/or thicknesses that are not amenable to industry standards in mechanical characterization. The macro-scale composite structures cannot be destructively sectioned into more standardized test specimens without detrimentally affecting the properties, resulting in inaccurate properties characterization. Additionally, the energetic nature of these materials creates a requirement for non-standard characterization equipment capable of mitigating safety hazards. Furthermore, the high pressures, loading rates, strains (deformation) and strain rates typical of advanced high speed weapons also drive unique requirements for experimentation and characterization. The development of multi-functionality in munitions, particularly with energetic materials is a relatively new field and adequate characterization is necessary for sensitivity and performance validation.

The intent of this topic is to develop material models and experimental methods and measurements to safely and accurately extract fundamental properties from as manufactured reactive material components. The proposed techniques should specifically address characterization of dynamically fractured cases to include parameters such as fragment velocities, fragment shapes, mass distributions, strain rates, etc. Additionally, all tools/equipment must be installed or built at the Air Force Research Laboratory's Munitions Directorate for in-house use.

PHASE I: Develop material models and experimental methods for performing complete characterization of dynamically fractured cases across a range of conditions. Preliminary evaluation of models and methods must be provided. Models must be suitable for implementation into available hydrocodes and finite element programs.

PHASE II: Optimization and demonstration of experimental methods developed in Phase I across a range of conditions through non-destructive techniques. Validation of material models developed in Phase I.

PHASE III: Demonstration of material models and experimental methods on a range of SRM/compositions/microstructures with varying geometries and/or thicknesses under a range of conditions. Experimental methods could be used commercially for quality control or NDE for unknown or irreplaceable components.

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3. K.M. Jaansalu, M.R. Dunning, and W.S. Andrews. “Fragment Velocities from Thermobaric Explosives in Metal Cylinders,” Propellants, Explosives, Pyrotechnics, 32 (2007): 80-86.

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KEYWORDS: reactive structures, structural reactive composites, energetic structures, energetic materials, warheads, dynamic fragmentation of reactive structures, dynamic fragmentation

AF151-118 TITLE: Physics-Based Modeling for Specialty Materials at High Temperatures

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a physics-based model to accurately predict high temperature special technology coating and substrate interaction, performance, durability, and wear life in engine/aircraft high temperature exhaust regions.

DESCRIPTION: There is a desire to improve the overall performance of high temperature special technology coatings to decrease sustainment cost and increase reliability. These coating/substrate systems are expected to benefit from modeling and analysis aimed at understanding and identifying the performance capabilities, failure mechanisms, and multi-element interaction of this complex and dynamic environment.

The coating and substrate need to be modeled as an interactive system. The model must consider and take into account the impact of environmental exposure (e.g., water, fluids, oxidation), dynamic and static strain effects, high temperature particulate impacts and abrasion, multi-frequency (low through high frequency inputs) vibrational effects, coefficient of thermal expansion mismatches between the coating and the substrate, etc. Furthermore, the model needs to be able to identify the effect these interactions may have on the performance, durability, and adhesion of the coating within this environment. The model needs to be capable of accurately depicting and recording these simultaneous interactions utilizing physics based algorithms with the current coating system, any repair to this coating system utilizing current repair material and processes, and be flexible enough to evaluate alternative coatings or repair materials.

Current state of the art for modeling the specified environment is limited to simple temperature modeling that does not accurately represent the environment or provide predictive durability / wear-life modeling. It may be possible to leverage learning and models developed for thermal barrier coating systems, although special technology coatings are more complex, containing multiple phases as well as significant porosity, which complicates analysis. There are also on-going Government exhaust area analyses that may be leverageable to support the depiction of the exhaust zone during normal operations. The Government developed data may be provided to the awardees as it is available and sharable. The material coating(s) to be used in the development of the model will be surrogate material that will be identified by the Government.

The model is intended to be utilized to develop more durable special technology material coating for current platforms. These alternative coatings will be transitioned to the appropriate platform of interest based on their performance and availability of funding. In addition, the model is intended to support development of capabilities by supporting the analysis of durable materials for the anticipated system environment and operational usage.

PHASE I: Identify and develop material model of coating: Develop coating model with substrate and environmental effects. (Government information concerning the exhaust environment may be available.) Model a normal flight profile in the exhaust environment. Verify that the model is stable and represents physics present in the system. Demonstrate model’s predictive capability and document the results.

PHASE II: Expand model to two other coating/substrate pairs to be identified by the Government: Develop and expand the model to include additional environments. Demonstrate ability to model a repair area and predict the wear life of the repair and surrounding area. Demonstrate model’s ability to support and feed higher level modeling. Verify that the model is stable and represents physics present in the system. Demonstrate the model’s predictive capability and document the results.

PHASE III: Further expand the model to loaded binder: Demonstrate ability to depict coatings' duration and wear in new environments. Verify that the model is stable and represents physics present in the system. Demonstrate ability of model to predict real-world coating performance and predict wear.

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KEYWORDS: coatings, ceramics, sustainment, durability, repair, physics based modeling, high temperature, environmental exposure, dynamic and static strain, vibration, coefficient of thermal expansion

AF151-119 TITLE: Development of Flaws in Complex Geometry Coated Turbine Engine Components for Vibrothermography NDE

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop, demonstrate, and verify a method to cost effectively and reliably induce controlled cracks of relevant sizes into various coated turbine engine components of interest for nondestructive evaluation (NDE).

DESCRIPTION: There are numerous metallic turbine engine components that are coated for one reason or another. Some components are stationary while many are rotating. Coatings are applied for environmental barrier protection to protect from the flow of harsh, corrosive gases; thermal barrier coatings to insulate and protect the base metal from large and prolonged heat loads; coatings to prevent galling or fretting where components slide while in contact with other components; and coatings used on sealing surfaces to minimize propulsive loss and maximize propulsive efficiency. These coatings can be applied by themselves or in combination on different locations of the same component. During the normal depot component inspection the coatings must often be removed prior to inspection of the base material. If the component passes the inspection, it must be recoated to be put back into service. For high value parts, this procedure is performed often. For low value parts, it is usually more cost effective to scrap the part and purchase new since the cost to strip-inspect-recoat exceeds the 70 percent threshold of the cost of a new part. In both cases it is desiresable to have a whole-field inspection capability to inspect the component without removal of the coating regardless of the size and geometric complexity of the component. This will impact affordability and availability of fielded and future aerospace weapon systems by extending service life, ensuring flight safety, reducing sustainment costs, and ensuring mission readiness and capability.

The capability to inspect coated parts via vibrothermography has already been demonstrated and is successfully being used in the commercial sector. For use in the Air Force depot, a reliability assessment must ultimately be conducted before it can be implemented. Current state-of-the-art for any NDE reliability assessment method (e.g., eddy current testing, fluorescent penetrant testing, vibrothermography, etc.) is to produce cracks in specimens of relatively simple geometry. Cracking is performed on specimens usually with a starter notch which is grown to a controlled size in fatigue. The Phase I and Phase II SBIR effort is not to perform a reliability assessment. The technical challenge for this Phase I and Phase II SBIR is to develop, demonstrate, and verify a methodology to cost effectively and reliably induce controlled cracks of relevant sizes into specified regions in real coated turbine engine components, component features, and component geometries of interest as a prelude to a reliability assessment. Crack size range desired for Phase I is from 0.010" L to 0.040" L surface crack with a length-to-depth ratio of 2:1 to 3:1, and a corner crack range of 0.005-0.020" L. A maximum of two (2) each of coated turbine engine blades, turbine engine vanes, and turbine engine air seals, will be provided by the Government for Phase I. A larger quantity yet to be determined, will be provided by the Government for Phase II.

PHASE I: Develop, demonstrate, and verify a method to reliably induce controlled cracks in real coated turbine engine components. Any method can be used, the goal is to simulate a tight fatigue crack. The final configuration must be coated with the crack. Recoating is acceptable. Metric for success is a controlled crack length to within 25% of the target size successfully excited with vibrothermography.

PHASE II: The objective of the Phase II effort will be to scale-up the methodology and fabricate a statistical quantity of cracked coated turbine engine blades, vanes, and air seals, of appropriate crack size range to be used in an NDE reliability assessment in accordance with the process defined in MIL-HDBK-1823. The appropriate number of components will be provided by the Government. Note: This Phase will not perform the actual reliability assessment.

PHASE III: Perform a reliability assessment with vibrothermography first in a relevant environment and then in an operational environment in accordance with MIL-HDBK-1823. The objective is to transition the capability for Air Force depot NDE.

REFERENCES:
1. Vibrothermographic crack heating: A function of vibration and crack size, Stephen D. Holland. Christopher Uhl. Jeremy Renshaw, Review of Quantitative Nondestructive Evaluation, Vol. 28.

2. The sources of heat generation in vibrothermography, Jeremy Renshaw, John C. Chen, Stephen D. Holland , R. Bruce Thompson, NDT&E Volume 44, Issue 8, December 2011, Pages 736–739.

3. Vibration-induced tribological damage to fracture surfaces via vibrothermography, Jeremy Renshaw, Stephen D. Holland, R. Bruce Thompson, James Anderegg, International Journal of Fatigue 33 (2011) 849–857.

4. Quantifying the vibrothermographic effect, Stephen D. Holland, Christopher Uhl, Zhong Ouyang, Tom Banteld, Ming Li, William Q. Meeker, John Lively, Lisa Brasche, David Eisenmann, NDT&E, Volume 44, Issue 8, December 2011, Pages 775–782.

KEYWORDS: vibrothermography, crack, coating, nondestructive inspection, NDI, nondestructive evaluation, NDE

AF151-120 TITLE: <u>Linking Coupon to Component Behavior of CMCs in Relevant Service Environment</u>

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop an innovative method to link the durability of ceramic matrix composite test coupons to components in relevant service environments.

DESCRIPTION: Much of the innovation in gas turbine engine technology is driven by advanced materials technology. Ceramic matrix composites (CMC) are a promising high temperature material for aerospace applications. Recently, several successful demonstrations of CMC hot section turbine engine components have been executed. There are several benefits in using CMCs over traditional Ni-based super alloys which include improved durability at elevated temperatures, increased thrust-to-weight ratio and improved specific fuel consumption. While the need for CMCs is apparent, the current transition path for materials is based on metal alloys and does not account for the unique aspects of CMCs. Innovative testing methodologies and physics based computational tools that capture relevant environmental factors while accounting for the unique aspects of CMCs are needed to fully exploit their use for hot section turbine engine components.

Most of the current research and available property data on CMCs are based on flat panel coupon testing. However, CMC components in advanced turbine engine applications are highly complex. Components such as turbine blades and vanes require ply drops, curved plies, and/or matrix rich regions which have not been studied extensively. Additionally, the complexity of the CMCs architecture could cause other manufacturing defects such as porosity and ply wrinkles that can affect component durability. These components also face combined mechanical loading and thermal gradients resulting in complex stress states that are not captured in most standard tests. Combined environmental and mechanical damage will have a significant impact on CMC component life.

The evaluation of CMC turbine engine components in relevant service environments requires the application of extreme environments (high pressure, hot gases and moisture) and complex loads (bi-axial, vibratory and thermal gradients). Despite using established testing methods designed for metals throughout the component's building block development (coupons, sub-elements, sub-scale components, etc.), unanticipated failures still occur when the hardware is rolled up into a complete full scale engine demonstrator test in part due to the complexity of the loading and service environment. Preexisting service damage also impacts the service life CMC components.

Consequently, new and innovative methods are needed to verify the anticipated component performance and generate confidence in new designs and technologies as early in the development process as possible, while providing a reduction in cost and test time prior to their introduction into full-scale engines. Currently, empirical curves are generated from design allowables of flat panels to life CMC components. The current approach requires a prolonged development time and does not capture the complexity of CMC components. The preferred method will combine experimental and analytical aspects with the goal of developing lifing tools to reduce the amount of testing needed and capture the complexity of CMCs. The proposed method needs to predict the service life of CMC engine components within a determined fidelity of prediction. It also should focus on first order effects that limit service life. The proposed method can also provide insight into potential issues in the full-scale engine. Approaches will directly address and support DoD's next generation of propulsion technology initiatives, such as ADVENT and AETD within the VAATE program.

PHASE I: Identify and explore one or more approaches to capture the complexity of a CMC engine sub-component/component. Develop a conceptual model (analytical or numerical) and/or an ambient environment test to demonstrate feasibility for a relevant service environment in Phase II. Identify and prioritize the key technical challenges and show how they could be mitigated.

PHASE II: Apply chosen approach to a prototype sub-component/component test that captures key environmental factors. This approach should demonstrate its ability to predict the service life of the CMC sub-component/component based on coupon data with a determined confidence of prediction.

PHASE III: The anticipated solutions will have a major beneficial impact on predicting the service life of CMC components and will accelerate the time while reducing the cost to implement new aerospace propulsion technologies for both military and commercial applications.

REFERENCES:
1. T. Kim, "Thermo-Mechanical Characterization of Silicon Carbide/Silicon Carbide Composites at Elevated Temperatures Using a Unique Combustion Facility," PhD Dissertation, Air Force Institute of Technology (AFIT), 2009.

2. R.S. Kumar and G.S. Welch, "Delamination Failure in Ceramic Matrix Composites: Numerical Predictions and Experiments," Acta Mat. ,Vol. 60, pp. 2886-2900, 2012.

3. T.Z. Engel, "Ceramic Matrix Composite Turbine Blade Development," 37th Annual Conference on Composites, Materials and Structures, January 2013, Cocoa Beach, Fl.

4. M.C. Halbig, M.H. Jaskowiak, J.D. Kiser and D. Zhu, "Evaluation of Ceramic Matrix Composite Technology for Aircraft Turbine Engine Applications," 51st AIAA Aerospace Sciences Meeting, January 2013, Grapevine, Texas, Vol. 9, pp. 7964-7974.

KEYWORDS: CMC testing, sub-component durability, burner rig testing, high temperature testing, behavior and life prediction, damage modeling, oxidation modeling

AF151-121 TITLE: Improved Life Cycle Management of Airborne Systems Tools

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Improved life cycle management of airborne systems by integrating computational corrosion models and structural analysis tools

DESCRIPTION: With rising procurement cost and shrinking budgets, sustainment of existing aircraft is a priority. An improved life cycle management tool that helps inform sustainment decisions and extends remaining useful life of aircraft is essential for decreasing total ownership costs. Corrosion can cause stress corrosion cracking in high strength steel and aluminum components. Corrosion can also reduce the fatigue resistance of airframe components via corrosion assisted fatigue, resulting in sometimes-wasteful repair or removal from service. Current corrosion fatigue lifing methods provide expensive, yet only rough estimates of corrosion degradation. Fatigue failure due to corrosion is a multi-disciplinary, multi-scale problem that needs to integrate multiple mechanisms for accurate simulation of the damage state and better prediction of failure risk. In this effort, the contractor should select an environment and identify load cycles that will induce corrosion and mechanical damage in a representative aluminum structures, such as those constructed of 2000 and 7000 series aluminum alloys. The contractor may choose either stress corrosion cracking and/or a corrosion-fatigue mechanism. In order to account for the variability that exists in the material and loading conditions, the approach needs to be probabilistic. The prediction of the remaining useful life of aircraft structure requires modeling the evolution of the damage state of the structure in response to corrosion as well as fatigue or sustained load as the case may be.

PHASE I: Demonstrate the feasibility of using a computational life cycle management tool that integrates structural finite element models with stress corrosion cracking model(s) or corrosion fatigue model(s) to assess the probability of damage.

PHASE II: Build an integrated computational model that combines state-of-the-art corrosion and structural (integrity) models and demonstrate prediction of a corrosion-assisted failure on a representative aircraft component.

PHASE III: Demonstration of computational tools in realistic environments.

REFERENCES:

1. Scientific advances enabling next generation management of corrosion induced fatigue, James T. Burns and Richard P. Gangloff, Procedia Engineering 10 (2011) pp. 362-369.

2. Predictive modeling of localized corrosion: An application to aluminum alloys, J. Xiao and S. Chaudhuri, Electrochimica Acta Volume 56, Issue 16, June 2011, pp. 5630-5641.

3. Stochastic modeling of pitting corrosion in aluminum alloys, N. Murrer and R. Buchheit, Corrosion Science, volume 69, April 2013, pp. 139-148.

4. Stress corrosion cracking of two aluminum alloys: a comparison between experimental observations and modeling, Corrosion science volume 40, Issues 2-3 1996, pp. 251-270.

KEYWORDS: life cycle management, computational models, corrosion, aluminum alloys

AF151-122 TITLE: NDI Tool for Corrosion Detection in Sub-Structure

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop inspection technology to detect corrosion on 0.25” Al substructure under 0.2” Al or up to 0.5” composite surface layer. Goal is a field system to detect and quantify corrosion greater than or equal to 0.075” in diameter with a depth of 0.02”.

DESCRIPTION: Fighter aircraft have exhibited corrosion of aluminum structure beneath a 0.2 inch thick Al or up to 0.5-inch thick IM7 5240-4 (carbon fiber weave, epoxy resin) composite surface layer. Commercial aircraft have also exhibited corrosion under similar aluminum/ aluminum stack-ups. Corrosion results from the intrusion of water at gaps between exterior panels. These gaps are filled with a polymeric material that cracks allowing water to wick into the interface forming a galvanic couple. Current inspections remove the surface layer to inspect the underlying structure. While effective, this method is very time consuming and costly. Traditional eddy current and ultrasound approaches have been used to detect corrosion beneath the surface layer but have proven ineffective. Backscatter X-ray techniques have demonstrated promise, but poor resolution and slow scanning rates have limited their transition. Advanced or enhanced signal analysis methods could be applicable to this particular problem. The specimens described in this topic will be constructed with composite/metallic and metallic/metallic stack ups. The specimens for this topic will be limited to two (2) layers. For the composite/aluminum specimens, the composite panels should be composed of IM7 5240-4 (carbon fiber weave, epoxy resin), while the aluminum structure should be Al 2123-T8151. For the aluminum/aluminum specimens, the surface layer should be Al 7475-T761 while the substructure should be Al 7050-T7451. Specialty coatings and paints could be applied to the surface layer, which could hinder the inspection. In addition there could be surface treatments (anodizing, chemical coatings, or primers) applied to the substructure that could affect the detection. The Air Force will define which coatings and surface treatments will be used with the specimens for each of the different phases of this topic. However, the Air Force will not provide any materials for the construction of specimens. If detection of the objective corrosion size is not feasible, a larger area, 0.150” in diameter with a depth of 0.05” in depth, would be an acceptable threshold limit.

PHASE I: Develop and test technologies to detect material loss and corrosion. Use specimens to simulate corrosion in the aforementioned stack-ups. Empirically show that the developed method is capable of detecting the objective or, if necessary, the threshold limits, or give a timetable for further development needed to achieve the desired goal.

PHASE II: Develop a prototype system for field portable applications to detect/quantify corrosion metal loss in terms of area and depth. Demonstrate and validate the inspection system capability on a composite and aluminum stack-up configurations to be defined by the government. Specialty coatings may be applied to a number of these stack-ups to more closely replicate the structural configuration.

PHASE III: Refine inspection technology to include system's user interface, and usability via demonstrations and user feedback. Refine the system to meet specific portability, safety and survivability requirements.Conduct extensive capability demonstrations to statistically quantify the detection capability.

REFERENCES:

1. TO 33B-1-1, Standard Practice for Nondestructive Inspection Methods, Basic Theory.

2. MIL-STD-1530.B (1), Aircraft Structural Integrity Program (ASIP).

KEYWORDS: NDI, corrosion detection, corrosion mitigation, advanced/enhance signal analysis methods

AF151-123 TITLE: Structural Health Monitoring Methods for Aircraft Structural Integrity

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop structural health monitoring technology compatible with the U.S. Air Force Aircraft Structural Integrity Program (ASIP) environment. Reduce the maintenance burden associated with structural integrity inspections while maintaining safety.

DESCRIPTION: The U.S. Air Force uses a damage tolerant design approach to ensure the structural safety and reliability of the airframes of its fleet. A critical facet of this damage tolerant design approach is nondestructive inspection. These inspection ensure that a critical crack is not present in the inspected region and that any detection capability is sufficiently small that any undetected defects will not grow to critical size during the next service interval. While this approach is effective, the maintenance burden associated with repeated inspections can be problematic for some platforms. The inspections can be difficult and significant disassembly of the structure can be required to gain access to the inspection areas. Since there are typically many inspection points on an aircraft, this can result in significant cost and downtime for the aircraft.

Unconventional approaches to facilitate or replace these aircraft structural inspections,compatible with the US Air Force Aircraft Structural Integrity Program are desired. developed technologies are expected to include, but are not limited to. various forms of in-situ, nondestructive inspection techniques. New technical approaches are sought that do not revisit methods already presented and/or demonstrated in flight [4]. Specific capabilities must address variability and complexity found in typical aircraft structure, such as joints, irregular geometry, and time varying / stochastic boundary conditions. For these reasons, baseline comparison methods are not of interest unless they address the stochastic instability of the baseline condition and its influence of the probability of detection of the damage detection system. The developed technologies must be suitable for robust operation in the austere flight/field environments with limited maintenance and low false call rates.

In Phase I, examine the technologies that could significantly reduce the inspection burden at affordable costs. Identify new or improved methods to sense damage and define how they could be made inexpensively yet durably. Identify new nondestructive techniques that could increase reliability of the process but could be done quickly. Suggest methods that will increase the probability of detection and decrease the probability of false alarms that follow the guidance put forth in Reference 1.

In Phase II, there would be a demonstration of the most promising technology, technique or method to show that an in-situ nondestructive inspection system can be evaluated to enable the determination of its validated capability, i.e., probability of detection, to detect typical damage of interest, namely fatigue cracks in metallic structure consisting of aerospace qualified aluminum and/or titanium. Nominal sizes to be detected are approximately 0.1" corner notches. These defects should not consist of through-thickness holes or notches in open flat plates, but represent a typical multi-layered structure with one or more layers being at least 0.15" thick with fasteners and/or other geometry features.

In Phase III, structural health monitoring methods/approaches would be extended into the commercial markets. Markets outside of aerospace include transportation, infrastructure, automotive, naval and/or commercial shipping, and power industries,

PHASE I: Demonstrate novel approaches for Structural Health Monitoring for Aircraft Structural Integrity to provide proof of concept scalable to a full size aerospace structure addressing stochastic variability, complexity, and time-dependent change as described. Outline an approach to validate the system that follows the general guidance of Ref. 1 to ensure compliance with MIL-HDBK-1530C (ASIP).

PHASE II: Develop and conclusively demonstrate a prototype application or family of applications in a relevant environment. Partner with a potential end user of the technology to maximize the relevance of the demonstration and facilitate subsequent transition/commercialization.

PHASE III: Commercialize the resulting structural health monitoring methods/approaches.

REFERENCES:
1. J.B. Brausch and G. Steffes, "Demonstration, Qualification, and Airworthiness Certification of Structural Damage Sensing (SDS) Systems for Air Force Applications," AFRL-RX-WP-TM-2013-0062, available at www.dtic.mil.

2. MIL-HDBK-1530C, General Guidelines for Aircraft Structural Integrity Program (ASIP).

3. Air Vehicle Integration and Technology Research (AVIATR) Delivery Order 0002: Condition Based Maintenance Plus Structural Integrity (CBM + SI) Strategy Development, Final Report, Nov 2010, DTIC Number ADA546937.

4. E.A. Lindgren and D. Stargel,"USAF Perspective on Foundational Challenges for Enhanced Damage Sensing," Rev. Prog. QNDE, V32, 1839, AIP (2013).

5. F.K. Chang, ed., Proceedings of the 1st through 9th International Workshop on Structural Health Monitoring, DEStech Publications, Inc., Lancaster, PA.

KEYWORDS: health monitoring, structural integrity, non-destructive inspection, nondestructive inspection, NDI, damage tolerant design, lifecycle management, life cycle management, aircraft availability, total ownership cost

AF151-125 TITLE: Automated 'Tier 0' Defect Inspection for Low Observable Aircraft

TECHNOLOGY AREAS: Materials/Processes

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Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Design and demonstrate an automated inspection technique providing rapid and accurate identification, characterization, and coordinate registration of visual defects in the outer mold line of modern fighter/bomber aircraft.

DESCRIPTION: The tracking of defects visible with the human eye (Tier 0) on the outer mold line (OML) of modern fighter/bomber aircraft is required for accurately assessing the health of aircraft coating systems. Current manual inspection techniques take two technicians 4-6 hours to complete and are prone to human error. The desired automatic Tier 0 inspection system is anticipated to free up valuable man hours to address repair defects and normal time interval maintenance items. The Air Force desires a system with the ability to rapidly inspect the entire OML while automatically recognizing, characterizing, and registering defect positional information tied to the aircraft coordinate system. Precise 3D orientation of the defect is desired. The tool should inspect the entire OML thoroughly with inspection of wings, doors, horizontal and vertical tail(s), and fuselage required. However, inlet and exhaust duct inspection is not required for the purpose of this this solicitation. The system must sense and classify defects as accurately as a human technician with the objective of performing inspections more accurately in a shorter period of time. The system must be able to repeatedly identify a defect with an accuracy of 100 percent (objective) and 95 percent (threshold).

The system shall be capable of detecting a variety of surface defects such as cracks, gouges, and missing materials. Small surface anomalies can vary in size and depth, but for this application the system must be capable of detecting cracks on the order of 0.005 inches in width, length and similar depth. For location accuracy, the inspection system must be able to precisely identify defects within 0.5 inches.

The automated Tier 0 system must be portable, easy to set up and tear down, and capable of operating in an aircraft environment (Class I Division II). For example, the system must be explosion proof and resistant against any harmful chemical or oil it could encounter in a hangar. Collision avoidance technology should be incorporated into the design to protect the detection system as well as the coatings of the platform being inspected. If the inspection tool directly operates on the surface of the OML, it shall not damage any surface or coating on the aircraft.

A 5 skill level Air Force maintenance technician journeyman should be able to use the tool with minimal training. An open software architecture is desired so that output data files are compatible with various field assessment systems for any platform. If the inspection system is battery-powered, the system must be able to complete an entire OML inspection on a single battery charge.

PHASE I: Design an automated system capable of measuring aircraft features and detect, characterize, and register defect positional information. Demonstrate basic operation, including an interrogation technique and software algorithms in a laboratory setting on a small scale article and write a report with a bill of materials. The prototype system may be a "brassboard" with developmental software.

PHASE II: Fabricate an integrated system based upon what was demonstrated in Phase I. Demonstrate the prototype's ability to scan a large complex target while accurately registering and quantifying defect characteristics and positional data to the target coordinate system. Document the results of in a detailed report. Develop a manufacturing plan for a fully integrated ruggedized system capable of rapidly inspecting full scale aircraft in field or depot locations.

PHASE III: Develop and execute a transition plan to military and commercial customers based on requirements.

REFERENCES:
1. "Coating Inspection Data Reproducibility," http://www.sspc.org/media/documents/tech/AprTech11.pdf.

2. M.L. Smith, "Surface Inspection Techniques: Using the Integration of Innovative Machine Vision and Graphical Modeling Techniques," Engineering Research Series, 1st Ed., Duncan Dowson Ed., ISBN-10: 1860582923, ISBN-13: 978-1860582929, Wiley, 2001.

KEYWORDS: defect, coating, identification, inspection, crack, material, urethane, silicone, optical

AF151-126 TITLE: Uncertainty Propagation to Modal Parameters and Metrics

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To develop a methodology to propagate measurement error and quantify uncertainty of parameters and assurance criterion that are used to support model verification and validation efforts.

DESCRIPTION: Increasing fiscal constraints and technology advancements have steered the Department of Defense (DoD) to increased reliance on modeling and simulation. DoD policy dictates that models, simulations, and associated data used to support DoD processes, products, and decisions shall undergo verification and validation (V&V) throughout their life cycles. For example, in the case of structural dynamic finite element models modal parameters and assurance criterion are often used as metrics for model updating and validation. Additional examples include models relevant to Integrated Computational Materials Engineering (ICME) or component inspection requirements. Unfortunately, experimentally determined properties are rarely presented with any quantified statistical confidence or uncertainty. This is primarily due to the extensive amount of data reduction that must be accomplished to estimate properties from measurements. Raw time data must first be processed and then curve fit to estimate parameters. The raw data contain inherent precision and bias errors that are propagated to the validation metrics. Confidence in a model that is calibrated to or validated against measured properties and assurance criteria cannot be realized without a quantification of the uncertainty associated with the validation data.

This topic proposes that a methodology be developed to propagate uncertainty from experimental measurements to model parameters as well as relevant metrics used for validation.

The tools developed under this research should provide the following capabilities:
1. Propagate measurement error from measurements to estimated model parameters for common model parameter estimation algorithms.
2. Propagate measurement error from measurement to assurance criteria.
3. Demonstrate the validity of the error propagation methods developed.

PHASE I: Demonstrate the feasibility of an error propagation methodology on a single algorithm.

PHASE II: Complete full development and validation of the error propagation and uncertainty quantification methods for a model relevant to DoD needs. Complete full development and validation of error propagation and uncertainty quantification methods validation metrics. Demonstrate error propagation methodologies on a realistic representative test case. Document error propagation methods in final report.

PHASE III and DUAL USE APPLICATIONS: The error propagation methods developed can be used to improve confidence in model validation for commercial applications aerospace, automotive, industrial machinery. DoD/DOE will benefit from increased confidence in model validation for ICME, inspection, or structural health monitoring applications.

REFERENCES:
1. MIL-STD-3022, “Department of Defense Standard Practice Documentation of Verification, Validation, and Accreditation (VV&A) For Models and Simulations,” 28 January 2008.

2. DODI 5000.61, “DOD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A)," 9 December 2009.

KEYWORDS: uncertainty analysis, model parameter estimation, modeling and simulation, verification and validation

AF151-127 TITLE: Man-Portable Fire Suppression and Rapid Insulating/Cooling Agent

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop agent capable of providing a fire suppression agent for combat rescue with an additional capability to insulate or cool materials with the intent of providing a safe avenue for rescue in a fire-related recovery.

DESCRIPTION: In response to a DoD JUON (Joint Urgent Operational Need) for man-portable fire extinguishment; the Guardian Angel Program funded several Macaw Backpack units that use Aqueous Film Forming Foam (AFFF) as the agent. The AFFF was sufficient at putting out a fuel fire, but it showed little capability in insulating or lowering the temperature of the fire affected areas. AFFF is the current state of the art method, however, Air Force Special Operations Command's Pararescue (PJ) community has placed an additional requirement of insulating or cooling objects/materials to create a path to recovery and allow for human contact with the fire affected area.

Both the agent and the delivery system have been identified as areas for improvement. The main focus of this effort is expected to be development of the agent. The agent developed should have the ability to suppress fires, both Class A (ordinary combustibles) and Class B (fuel fires). The agent should also insulate or cool materials, allowing personnel to access scenes where both fire and heat are a force protection issue.

It is expected that insulation is a more feasible approach to protecting the user from heat from objects. Metals have a high thermal mass and high conductivity, so it is unlikely to be able to cool an entire structure. It may be possible to insulate surfaces in a layer of an agent, leaving a coating on the surface with a temperature low enough for a person with gloves to handle. The agent would solve the user's needs by providing a layer of thermal resistance.

The agent developed should be safe for human interaction, as the agent is likely to come into contact with human skin, clothing, and footwear. The agent is likely to be used in close quarters, so the agent should not pose an inhalation hazard.

Past efforts have theorized the capability to project the fire suppression agent from a safe distance. The name Snowball came from the concept of throwing a fire suppressant/cooling agent far enough forward to protect the recovery avenue. Delivery systems are not be expected as the main thrust of this effort, but an appropriate, man-portable delivery method must be utilized or developed in order to conduct testing during Phase II.

PHASE I: Develop an agent capable of extinguishing Class A and Class B fires as well as the ability to protect the user from a heat source through insulation or cooling. Provide lab scale demonstration to verify effectiveness before Phase II.

PHASE II: Demonstrate the agent in a relevant environment for effectiveness. Modify, develop, or improve a delivery method capable of dispensing the agent. The agent should be tested in a relevant environment for effectiveness. Additional, basic screening for environmental safety and human toxicity should be conducted, to include development of an MSDS.

PHASE III: Begin the transition process to bring the techniques and agents to the Guardian Angel/PJs community, as well as, firefighting/rescue services.

REFERENCES:
1. Underwriters Laboratories (UL) Standard 711, Rating and Fire Testing of Fire Extinguishers.

2. MIL-F-24385, Military Specification: Fire Extinguishing Agent, Aqueous Film Forming Foam (AFFF) Liquid Concentrates, Six Percent, for Fresh and Sea Water (21-NOV-1969).

3. National Fire Protection Association (NFPA) 412, Standard for evaluating Aircraft Rescue and Firefighting Foam Equipment.

KEYWORDS: Fire suppression, endothermic cooling, magnesium hydroxide, nano platelets, man portable, fire extinguisher, AFFF

AF151-128 TITLE: Robust Titanium Surface Preparation for Structural Adhesive Bonding

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a robust process/method that can prepare titanium (Ti-6Al-4V) surfaces rapidly and consistently for structural adhesive bonding while reducing touch labor and hazardous materials usage.

DESCRIPTION: Structural adhesive bonding is the preferred joining method to achieve more significant weight reduction and cost savings over mechanically fastened aircraft structure. However, in order to realize the benefits, the faying surfaces must be properly prepared in order to ensure a durable joint for the life of the aircraft. Common methods in use today for preparing these surfaces include abrasive techniques (e.g., sanding and grit blasting), chemical surface treatments, anodization, and etches prior to primer application. These techniques provide fresh surfaces for bonding that are free from contamination, but these techniques have disadvantages such as the following: hazardous material usage, time-consuming processes, required control of debris/residual contamination, and limited high-temperature product success. Automated energetic techniques have shown some preliminary success as alternatives to abrasive deoxidation methods in surface preparation processes, but work is needed to develop and demonstrate rapid, robust processes for structural adhesive bonding of titanium surfaces, including large areas on aircraft, in both Original Equipment Manufacturer (OEM) and field environments.

The dual-use commercialization potential exists. As mentioned previously, the military application is apparent in the increased use of titanium bonding in aircraft for weight reduction and cost savings. Other potential applications include ground vehicles. The technology can be used in OEM as well as depot/overhaul operations. In addition, the commercial aircraft industry is very interested in improved structural bonding techniques, as are other industries that use advanced bonding of titanium.

During Phase I, a technology transition plan should be developed along with an initial business case analysis. In Phase II, these documents should be updated and refined with additional data.

PHASE I: Demonstrate a method to improve the robustness of Ti-6Al-4V bonding process using a 350 degrees F cure epoxy adhesive (e.g., AF 191). Perform mechanical and durability tests to validate concepts (e.g., Wedge Extension, Lap Shear, FWT per applicable ASTM) and compare to currently-used baseline processes and bond process specification requirements.

PHASE II: Broaden testing to other adhesive materials systems of interest, as well as test environments and surface activation as a function of aging. Some examples include FM 300 and FM 300-2 adhesives, graphite BMI to Ti adherends, and various operating conditions (-65 degrees F, ambient, ambient moisture- conditioned, hot, and hot moisture-conditioned). Development of a bond process specification suitable for the manufacturing and maintenance environments is required for technology transition.

PHASE III: This work scope should include qualification of the bond process and automated tool (if applicable) for specific manufacturing and/or maintenance environments.

REFERENCES:
1. S.R. Brown and G.J. Pilla, “Titanium Surface Treatments for Adhesive Bonding,” NADC-82032-60, March 31, 1982.

2. Raymond F. Wegman and Javes Van Twisk, Surface Preparation Techniques for Adhesive Bonding, 2nd Edition, 2013.

3. M. Akram, K.M. B. Jansen, L.J. Ernst, and S. Bhowmiak, “Atmospheric Pressure Plasma Surface Modification of Titanium for High Temperature Adhesive Bonding,” International Journal of Adhesion and Adhesives, 31 (7), (2011), 598-604.

KEYWORDS: adhesives, titanium, Ti-6Al-4V, structural bonding

AF151-129 TITLE: Nondestructive Method and Data Analysis for Organic Matrix Composite Leading Edges

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop or optimize a nondestructive evaluation method and data analysis for convex surfaces of organic matrix composite edges (chine, airfoil) with an inner radii objective/threshold of 0.1/0.25 in. Defect sensitivity obj/thres 0.1/0.25 in. diameter

DESCRIPTION: Develop or optimize a nondestructive evaluation (NDE) method and data analysis routine for inspection of convex outer surfaces of organic matrix composite edges (i.e., chine, airfoil) with an inner radii objective/threshold of 0.1/0.25 in. NDE defect sensitivity objective/threshold of 0.1/0.25 in. diameter.

Air Force-relevant applications include, but are not limited to nondestructive evaluation/inspection (NDE/I) of organic matrix composite (OMC) materials used in leading edges, chines that enable manned or unmanned air systems or airfoils used in gas turbine engines. Currently all OMC components are inspected by NDE for defects before service and frequently during service as well. Available NDE techniques and data analyses are very capable of detecting defects in flat plate geometries. However, these methods and analysis tools have difficulty inspecting across the apex of curved parts like leading edges and airfoils while maintaining the required sensitivity to defects. Incremental improvements to current methods are not being sought. The intent of this solicitation is to address a very complex inspection requirement that has not been resolved by incremental engineering of the standard five methods (ultrasound, eddy current, radiography, magnetic particle and fluorescent penetrant). However, it is possible that the potential solution could be based on these methods. Measurements will occur in a variety of temperature and loading conditions on the structure or component when the measurement is performed. This means that the effect of temperature and/or load on the reproducibility and accuracy of the inspection capability must be addressed. Methods that use a baseline comparison (or subtraction) are not being sought. Method must be able to inspect through the thickness of the radii. Defects of interest include delaminations (real not simulated), foreign objects (e.g., backing paper, gloves or sticky notes), porosity, ply related defects (ply gaps, ply laps and ply wrinkles), and bridging. Bridging is defined as when the outer radius (OR) plies and inner radius (IR) plies separate from each other during processing, creating a void or cavity between them running along the edge). To further complicate the inspection space some of these components have additional filler materials, such as co-cured or pre-cured OMC ‘noodles’, which are placed between the OR plies and the IR plies to enable the OR to have a smaller radius than the IR. Components may have varying thickness values and other geometric features in addition to the complex curvature. It is expected that an NDE technique and the associated data analysis will need to be optimized and tailored to enable a single-sided (OR) inspection. The technique and analysis should not be so specific to the target application that it cannot be easily used on similar parts (different material, layup or radii) with minimal changes to the technique and the analysis.

PHASE I: Demonstrate and verify NDE technique and data analysis (NTDA) on a [45/90/-45/0]2s pre-preg OMC with a 0.25” or less IR. Must show sensitivity to objective/threshold 0.1/0.25 in. diameter foreign objects and delaminations (not inserted material). NTDA must be a minimum of TRL 4, "breadboard" prototype with fully functional, but not necessarily fully optimized data analysis in a lab environment.

PHASE II: Expand on the Phase I results through further improvements to the NDTA leading to a deliverable prototype. Finish optimization of NDTA and verify it by meeting defect sensitivity criteria in Phase I plus porosity, ply defects, and bridging. NDTA must be adaptable to USAF NDI CONOPS: specialized equipment allowed at depot and only current standardized tools in field. Focus is on quality control and depot inspections. However, there should be a well-defined development path to field implementation

PHASE III: Commercial aircraft and automotive manufacturers use OMCs. An example transition path is to partner with an Air Force system integrator, OEM and/or JPO to mature NDTA, and demonstrate it in an operational environment (i.e., OMC production or maintenance facility) on an OMC leading edge or airfoil.

REFERENCES:

1. Steven M. Shepard, "Quantitative Themographic Characterization of Composites," Residual Stress, Thermomechanics & Infrared Imaging, Hybrid Techniques and Inverse Problems, Volume 8, Conference Proceedings of the Society for Experimental Mechanics Series 2014, Springer, pp. 59-66.

2. Kwang-Hee Im et. al., "One-sided ultrasonic inspection to detect flaws in CFRP composite solid laminates," Proc. SPIE 8409, Third International Conference on Smart Materials and Nanotechnology in Engineering, 840939 (April 2, 2012); doi:10.1117/12.924234.

KEYWORDS: nondestructive evaluation, nondestructive inspection, NDE, NDI, data analysis, organic matrix composites, leading edge, chine, airfoil

AF151-130 TITLE: High-frequency Applications for Carbon Nanotube-based Wires

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop and demonstrate a light-weight, carbon nanotube-based conductor and finished cable assembly with reliable data transfer above 1 MHz and high frequency attenuation numbers comparable to copper.

DESCRIPTION: Recent research and development towards applications for conductive carbon nanotube (CNT) materials has opened up an entirely new market for decreasing mass on air and space platforms. As space and air vehicles become more complex with increased power and data requirements, cable harnessing represents a significant portion of overall vehicle weight. Furthermore, by exploring new opportunities to use nanotechnology on military space platforms, the domestic industrial base for this technology can be strengthened. As the military technology development for CNT-based wires continues, it is expected that commercial aerospace applications for this technology will become more compelling, further driving down the cost of CNT material.

By replacing primary copper conductors with CNT-based conductors in electrical cabling, significant weight savings can be realized. This reduced weight saves a considerable amount in launch costs for spacecraft and fuel efficiency for aircraft. Furthermore, due to the inherent flexure tolerance and environmental stability of CNT materials, CNT-based wires can provide added resilience in the face of natural or man-made electro magnetic interference (EMI) events.

While considerable research has been done into the development of low-speed data rate cables, an opportunity exists to increase the conductivity of CNT yarn and tape materials to implement high-speed data transmission CNT cables. Current development efforts have focused on the “low hanging fruit” of low-speed 1553 and twin-ax cables, but with further research into conductivity optimization, CNT-based wires could feasibly replace all copper data cabling on air and spacecraft.

This proposal seeks innovative doping and post-processing strategies for increasing the conductivity of CNT-based wires to implement reliable data transfer above the 1 MHz threshold- the current practical limit of existing technologies. A main objective of this project is to develop a process control and manufacturing strategy for expanding the scale of current research efforts, which have demonstrated promising conductivity results in a laboratory setting. Proposed technical solution should align with a domestic high-volume manufacturing source of CNT material, or demonstrate the rapid transfer feasibility to a large scale manufacturer.

The end goal of this technology is a CNT-based finished cable assembly that could serve as a drop-in replacement of existing copper-based high speed data cables.

The threshold attenuation numbers for the delivered cables should be less than 1.5 dB/100ft at 1 MHz (per Mil Std 1553). The objective attenuation for the final product should be less than 1 dB/100ft at 1 MHz.

PHASE I: Design a methodology for producing high-conductivity CNT wires, with equivalent attenuation to copper above 1MHz. Develop scalable post-processing strategy for CNT conductors that relies on existing manufacturing processes and can be rapidly inserted into the industrial base for wire and cable assembly.

PHASE II: Prepare test prototypes for high-frequency CNT cables meeting all applicable military specifications, while focusing on the development of a scalable manufacturing process. Identify and purchase necessary manufacturing equipment to develop pilot manufacturing line.

PHASE III: Commercialization through large-scale production capacity for high frequency CNT-based wires. Demonstrate performance equivalent to copper at reduced overall cable weights.

REFERENCES:

1. Harvey, Stefani E., "Carbon as Conductor: A Pragmatic View," International Wire & Cable Symposium (2013).

2. Jarosz, et al., “High Performance, Lightweight Coaxial Cable from Carbon Nanotube Conductors,” ACS Appl. Mater. Interfaces, 4, 1103-1109 (2012).

3. Zhao, et al., “Iodine Doped Carbon Nanotube Cables Exceeding Specific Electrical Conductivity of Metals”, Science Reports, 1, 83 (2011).

KEYWORDS: CNT, cables, harnessing

AF151-132 TITLE: Defect Mitigation Processes for III-V-based Infrared Detectors

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop processes which can be reliably used to lower the number of defects inherent to III-V infrared superlattice materials after growth via techniques compatible with existing detector fabrication technologies.

DESCRIPTION: The Air Force has multiple critical airborne and space-based applications requiring infrared detection systems with lower cost, size, weight, and power, increased resolution, larger formats, increased reliability, and improved sustainability. The III-V infrared superlattice materials hold promise to significantly lower the cost of existing infrared detection systems due to their advantages over present detectors comprised of bulk materials. These advantages, including less cooling required due to higher operating temperatures, increased manufacturability from leveraging domestic III-V foundries, and increased yield resulting from more uniform deposition on larger substrates, all translate into lower cost while maintaining or increasing performance. Although significant improvements over the last 20-30 years in III-V superlattice material growth, surface passivation, and detector fabrication have created the current state-of-the-art detectors (e.g., high operating temperature at about 150 K, mid-wavelength infrared focal plane array detectors), the remaining elusive materials defects are limiting the operating temperature from reaching 200 K. These defects are possibly point defects native to the materials, or they may be due to crystal defects, such as threading dislocations, resulting in dangling bonds within the material bulk. Such defects can act as deep level trap states, generation centers, or shallow level defect states that decrease the material minority carrier lifetime and Hall mobility and increase the detector dark current while lowering the quantum efficiency. By applying appropriate defect mitigation processes, the number of active defect states can be reduced, thereby improving the material properties necessary to optimize the detector performance for higher operating temperatures. Processes such as post-growth annealing and hydrogenation may improve the material minority carrier lifetime and mobility and thus the detector dark current and quantum efficiency, indicating promise to deactivate material defects behaving as scattering and recombination centers or as deep level traps. A variety of innovative post-growth process techniques may be proposed to address defect mitigation in infrared InAs/InGaSb and InAs/InAsSb superlattice materials and detectors.

The goal of this program is to systematically explore and develop post-growth defect mitigation processes that can improve the III-V infrared superlattice minority carrier lifetime by at least 10X, Hall mobility by 5-10X, and/or detector dark current by at least 10X at temperatures from 77 K to 200 K. These processes must be thermally compatible with arsenide-antimonide materials and not cause contamination or degradation of the superlattice materials. The stability of the defect mitigation processes must be assessed over time for at least six months and over temperature for at least 20 cycles from 77 K to 300 K.

The potential for future commercialization of these defect mitigation processes exists to improve device performance not only of III-V superlattice infrared detectors but also emitters (laser diodes, light emitting diodes) and multi-junction solar cells. Military applications, including Intelligence Surveillance and Reconnaissance as well as Space Situational Awareness, would benefit from the use of these improved high-performance infrared detectors for imaging and characterizing objects of different temperatures. Commercial applications of these high performance detectors include night-vision cameras, fire detectors, radiation thermometers, satellite-based and medical diagnostic imaging. Reduction of material defects will also improve the performance of laser diodes used in multiple medical applications and of solar cells used in energy applications.

PHASE I: Assess the feasibility of post-growth defect mitigation processes that increase the III-V infrared superlattice detector material minority carrier lifetime and mobility. Characterize the process effects on the material quality using design of experiments. Deliver representative test samples to the government.

PHASE II: Optimize the defect mitigation process identified in Phase I. Complete extensive material characterization to demonstrate the effectiveness of the process. Apply the process to small multi-element superlattice detectors to demonstrate dark current and quantum efficiency improvement capability. Demonstrate the defect mitigation process improvements for 256x256 or larger prototype focal plane arrays with focal plane test and evaluation. Deliver representative test samples to the government.

PHASE III: Military applications include Intelligence Surveillance and Reconnaissance as well as Space Situational Awareness imaging and detection. Commercial applications include cameras for night-vision, fire detection, radiation thermometers, and satellite-based and medical diagnostic imaging.

REFERENCES:
1. Boieriu, P., Grein, C., Velicu, S., Garland, J., Fulk, C., Sivananthan, S., Stoltz, A., Bubulac, L., Dinan, J.H., “Effects of hydrogen on majority carrier transport and minority carrier lifetimes in long wavelength infrared HgCdTe on Si,” Appl. Phys. Lett. 88, 062106 (2006).

2. Haugan, H.J., Brown, G.J., Elhamri, S., Pacley, S., Olson, B.V., Boggess, T.F., “Post growth annealing study on long wavelength infrared InAs/GaSb superlattices,” J. Appl. Phys. 111, 053113 (2012).

3. Boieriu, P., Velicu, S., Bommena, R., Buurma, C., Blisset, C., Grein, C., Sivananthan, S., Hagler, P., “High operation temperature of HgCdTe photodiodes by bulk defect passivation,” Proc. SPIE 8631, 86311J-6 (2013).

KEYWORDS: passivation, hydrogenation, annealing, superlattice, antimonides, infrared detector

AF151-133 TITLE: Optical Materials Processing for High Linearity Electro-optic Modulators

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The goal of this effort is to develop processing for optically engineered materials to create high linearity, high performance electro-optic modulators. While higher sensitivity (lower V-pi) is desirable, so is higher linearity and dynamic range.

DESCRIPTION: Optically engineered devices for analog rf photonics are a relatively new and rich field of study. Electro-optic modulators are critical devices within high bandwidth analog optical systems, such as the photonic links connecting remote antenna stations on an aircraft to central processors. It is widely acknowledged that electro-optic modulators are key components with regard to increasing performance of electronic warfare receivers or other analog applications onboard aircraft. While optical processing is one of the strengths offered by rf photonic technology, it can be limited by the ability to process optical materials with high quality and precision for insertion into devices. Here we seek to develop processing of nonlinear optical materials for the purposes of extending the capabilities of an important device for rf photonics, the electro-optic modulator.

Previous efforts on optically engineered electro-optic modulators have targeted increasing sensitivity through slow light effects or resonant cavities.These modulators are for example created by fabricating photonic crystals, Bragg gratings, or ring cavities within the modulator. There are also results that have used post modulation optical filtering to achieve more linear responses, however they are fundamentally limited since it is not possible to post filter the third-order or second-order distortions that are already within the passband. It is therefore desirable to develop high quality nanostructured materials for the purpose of both linearization and increasing the sensitivity of electro-optic modulators. There is a fundamental difference between optical filtering of the modulated light after it exits the modulator, and having the modulator itself be comprised of a nanostructured material since the nonlinear mixing process is changed by that latter but not the former.

This solicitation is not targeting slow light enhancements, the goal is controlled in-situ optical filtering within traveling wave modulators. Therefore useful optical responses must be well controlled and be able to filter down to the 5GHz range if possible, with the sharper filtering effect being better. For instance, a Lithium Niobate modulator that is also has an optical passband including only the optical fundamental minus 50 GHz is a useful configuration. It should also be noted that the filtering may alter the light wave velocity and therefore the traveling wave configuration of the rf electrodes will likely have to be engineered to match. For this effort, the optical fundamental wavelength is 1.55 microns, meaning that fabrication will need approximately 300-400nm feature sizes to be able to replicate modeled designs. Feature sidewall roughness, lattice uniformity, and depth will be critical factors since losses must be strictly controlled for useful materials.

PHASE I: Demonstrate processing of a second order nonlinear optical material that can yield single mode waveguides and surrounding optical nanostructures for optical engineering of electro-optic modulators. Design a highly linearized single-sideband modulator for construction in phase II with total insertion loss of less than 6.0 dB, experimental data must support insertion loss estimate.

PHASE II: Fabrication and delivery of packaged electro-optic modulators with: 6.0 dB insertion loss or less, 60 GHz 3 dB optical bandwidth for first sideband, V-pi < 2 volts, and no third-order mixing products. It is expected that further design iterations and discussions will take place beyond phase I and that the design in phase may shift considerably in the process. The primary challenge will be materials processing for the creation of high quality nanostructured nonlinear optical materials.

PHASE III: Transition of devices to systems and platforms requiring these high performance modulators, such as electronic warfare systems that have stringent linearity requirements.

REFERENCES:
1. "Ultra-smooth $LiNbO_3$ micro and nano structures for photonic applications," Gwenn Ulliac, Blandine Guichardaz, Jean-Yves Rauch, Samuel Queste, Sarah Benchabane, and Nadège Courjal, Microelectronic Engineering, 88 (2011) 2417–2419.

2. "Free-Standing Lithium Niobate Microring Resonators for Hybrid Integrated Optics" Manuel Koechlin, Frederik Sulser, Zlatko Sitar, Gorazd Poberaj, and Peter Günter, IEEE Photonics Technology Letters, Vol. 22, No. 4, February 15, 2010.

KEYWORDS: photonic crystals, electro-optic modulators, second-order nonlinear optical materials, nonlinear Bragg gratings, rf photonics

AF151-134 TITLE: Data Management Tools for Metallic Additive Manufacturing

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop software tools to manage and manipulate process data from additive manufacturing processes and integrate these data with geometry definition, in order to affect the design and qualification process.

DESCRIPTION: Metallic additive manufacturing (AM) processes such as powder bed fusion and directed energy deposition offer the potential to fabricate components with location specific properties via spatial modulation of processing conditions, chemistry, or both. Such approaches entail the creation, manipulation, and storage of spatially varying process related data that is atypical of traditional cast or wrought component design and fabrication. Such data includes but is not limited to location specific process parameter values, material property target values, scan paths, process data collected during the fabrication process, and post build material characterization outputs. Such data is useful for a range of activities including process design and evaluation, AM process model calibration and validation, and possibly qualification.

There are many existing Computer Aided Design (CAD) tools with capabilities for geometry definition, manipulation, and evaluation. While some attempts have been made to integrate AM workflows into existing CAD paradigms [1], in general existing CAD tools are not AM "process aware" and do not have the capability to manage the necessary spatially varying process data. The Additive Manufacturing Format (AMF) recently defined by ASTM [2] provides more advanced capabilities than the traditional STL format, but is primarily focused on geometry definition and has limited support for spatially varying process data. Equipment specific proprietary AM process planning software is employed to specify process parameters and to create scan paths based on geometry input from a CAD file (often in the STL format). This processing information is passed directly to the AM hardware, and is not typically available to designers or engineers for process optimization and qualification efforts.

A framework that bridges the gap between existing CAD tools and proprietary AM planning software by managing all of the data associated with both the geometry and process itself could mitigate this problem. Such a framework would interface with conventional tools used to define the geometry as well as those for planning the AM process. It should provide capabilities to store and manipulate spatially varying process data generated as part of both the design and fabrication process. Additionally such a tool would allow for interfaces to third party process monitoring equipment, post process inspection and characterization tools, or even process modeling and optimization software.

A potential challenge is that the AM process data in question can be both specific to a particular AM machine as well as proprietary in nature. Possible approaches to mitigate this issue include strategically working with AM equipment hardware manufacturers, or the development of an application programming interface (API) that proprietary software could interact with directly.

PHASE I: Define requirements for an AM data management strategy by consulting with AM equipment OEMs, industry experts, AM vendors, and Air Force personnel. Perform an assessment to establish which AM hardware and CAD software will be targeted in Phase I. Initial efforts can focus on a single AM process, but consideration should be given to how choices impact applicability for other processes.

PHASE II: Implement the strategy defined in Phase I, including development of necessary software interfaces and data format. Demonstrate usage on a design test-case for a military or commercial aviation application by working with a combination of relevant industry partners, AM vendors, and AM equipment OEMs. Refine the implementation as necessary.

PHASE III: Improve software tool quality toward that required for commercial application. Expand the range of available interfaces to CAD tools and AM equipment/planning software based on customer demand. Demonstrate usage of the data management tool to affect the design of an AM component or process design.

REFERENCES:

1. Smith, P. C., Rennie, A. E. W. , "A Computer Aided Design (CAD) support tool for parametric design of products for Rapid Manufacture (RM)." Innovative Developments in Design and Manufacturing: Advanced Research in Virtual and Rapid Prototyping. p95-100, (2010).

2. ASTM Standard 52915, "Standard Specification for Additive Manufacturing File Format (AMF)." ASTM International, West Conshohocken, PA, (2013).

KEYWORDS: additive manufacturing, computer aided design, data management

AF151-135 TITLE: Research Tool to Support Hybridized Additive Manufacturing

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop a machine to support the research and development of additive manufacturing that is capable of depositing/building multiple material classes (i.e., metals, ceramics, polymers) on a substrate simultaneously (or near simultaneously).

DESCRIPTION: Additive manufacturing promises may benefits including, speed to market, low cost, and revolutionary capability facilitated by geometric complexity. Similarly, hybrid materials consisting of multiple bonded/joined/composited materials classes have long been viewed as promising revolutionary multifunctional capabilities if/when applied to Air Force components. Hybridization will allow components to be produced with properties tailored to need by location with overall minimization of weight and cost in mind. This topic seeks to merge these two revolutionary technologies to support the research and development of additive manufacture of hybrid structures.

Research and development of a manufacturing process requires both hardware and control software development. This topic focuses specifically on the development of hardware capable of handling and codepositing polymeric, metallic, and ceramic materials on any given substrate (polymer, metal, ceramic) to create a hybridized structure. To research and development, machine deposition capabilities need to be highly variable beyond expected production envelopes. The ability to modify the composition of any single material class may be required to accomplish hybridization. Such capability is of extreme interest. Deposition environment should be addressed to include atmosphere, intentional and controllable substrate and manufactured structure heating, and intentional and controllable substrate and manufactured structure cooling during processing. Hardware capabilities must be able to produce components ranging from electronic devices to small scale structural components. Instrumentation (i.e., sensors) to monitor all aspects of deposition/buildup is necessary to provide researchers with as much information as possible. Along with equipment development should be documentation of all information that will be necessary to develop control algorithms for the process.

The developed machine will ultimately be used to explore and develop potential processing windows for hybridized structures as well as builds structures to evaluate material class interface and component performance properties. Furthermore, instrumentation and complete processing environmental control will enable the development of process simulation models that would then be expected to greatly reduce the time to develop new hybridized material concepts and technical solutions. With such models in place the machine can be used to produce conceptual structures and facilitate model validation.

PHASE I: Develop the capability requirements for an additive manufacture of hybrids machine. Design a hybrids additive manufacturing machine that can meet the identified capabilities. Analyze technology readiness of key hardware components of the designed machine. Develop a plan to sufficiently develop low technology readiness hardware features.

PHASE II: Advance and demonstrate low technology readiness hardware features per the plan developed in Phase I. Assemble laboratory prototype machine and successfully demonstrate functional capability on individual materials classes (i.e., produce additive metallic structures, additive polymeric structures, and additive ceramic structures). Engage Air Force materials researchers to use the developed equipment on publically releasable research to demonstrate the potential commercial utility of the machine.

PHASE III: Incorporate lessons learned, further advance specific hardware feature technology and build a marketable hybrids additive manufacture machine.

REFERENCES:
1. Price Waterhouse Cooper, 3D Printing: A potential game changer for aerospace and defense, Gaining Altitude, Issue 7.

2. Gibson, Rosen, Stucker, Additive Manufacturing Technologies-Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010.

KEYWORDS: hybrid, hybrids, materials, additive manufacture, research and development

AF151-136 TITLE: <u>Modeling Tools for the Machining of Ceramic Matrix Composites (CMCs)</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop integrated modeling and simulation tools for the machining of ceramic matrix composites (CMCs).

DESCRIPTION: The application of ceramic composite materials to DoD turbine engines is continuing to increase due to their high temperature capability. The greater strength-to-weight ratio of CMCs compared to metals also allows designers to reduce weight, which in turn contributes to fuel burn savings. Machining CMC materials, however, is a complex task due to their heterogeneous nature. In addition, CMCs are easily damaged unless machining is performed properly. Finally, by the time the CMC component is ready for machining, the part has considerable value and the cost of scrapping is unacceptably high. Thus, the cost, difficulty, value and impact of that machining are high.

Multiple machining modeling software tools are currently available to simulate and optimize conventional machining processes for metal components. However, these software tools have limited ability to simulate and optimize CMC material machining because these materials, unlike metals, are anisotropic and consist of both unique ceramic resins and fibers. The focus of this effort is to develop a modeling tool for the machining of ceramic matrix composites potentially including silicon carbide (SiC/SiC) and oxide (Ox/Ox) based systems for use on DoD turbine engine components. Improved simulation tools in this area will reduce component costs by shortening machine utilization times and improving part quality and/or manufacturing yield.

One aspect of this effort will be the demonstration of a clear understanding of the material properties of CMCs and how these affect the machining process. The software tool should incorporate the CMC properties into simulations of material removal processes (drilling, milling, etc.). It should be able to define optimization bounds and output optimal process plans for CMC machining. In this context, the optimization process includes machining parameters as they affect total machining and setup time, the prediction of delamination and other forms of machine induced damage (location and severity) and traditional secondary machining factors (tool wear, etc.).

PHASE I: Develop and demonstrate a tool that simulates subtractive manufacturing processes for CMC materials. Identify key characteristics of material removal processes and the supporting properties needed to sufficiently model those processes while verifying approach relevance and viability with perspective users. Develop a business case and development plan supporting further investment and transition.

PHASE II: Develop and test the simulation tool on representative material removal processes for various complex geometries. Incorporate optimization into the material removal simulation and then verify and validate the simulation with representative manufacturing and materials configurations. The modeling tool and associated process must be shown to be robust, accurate and practical from a user standpoint.

PHASE III: The tool will be applied to an array of military and commercial CMC parts in order to optimize the manufacturing process. Military components will have the highest priority for expanded tool development to address technical and cost issues associated with conventionally machined parts.

REFERENCES:
1. Bansal, Narottam P. Handbook of Ceramic Composites. Kluwer Academic Publishers, 2005.

2. Davim, J. Paolo. Machining Composite Materials. Wiley-ISTE, Dec. 2009.

3. Dandekar, C.R. & Shin, Y.C. (2012) "Modeling of Machining of Composite Materials: A Review," International Journal of Machine Tools and Manufacture, Volume 57, 102-121.

KEYWORDS: ceramic matrix composites, CMCs, machining, modeling, process modeling, milling, drilling, software, optimization

AF151-139 TITLE: <u>Robust Light-Weight Doppler Weather Radar</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Produce Doppler weather radar for use by AFWA that detects 1 in/hr precipitation from 5-180 nm, winds up to 50 kt from 5-50 nm, 2-4 degree beamwidth, 360 deg azimuth and up to 60 degree elevation, transport volume and weight < 104x84x96 and 6790 lbs.

DESCRIPTION: The Air Force Weather Agency (AFWA) uses weather radar data and products to enable military decision-makers to obtain a timely and accurate picture of the operational environment and to maintain battlespace awareness. Real-time weather information is provided, in part, by portable Doppler radar weather systems that can be transported to deployed locations, setup quickly, and utilize DoD communications infrastructure. The weather information that these systems provide includes reflectivity for storm track information, velocity azimuth display, surface rainfall accumulation, and storm relative mean radial velocity; this data provides military weather forecasters with key information to issue weather warnings to protect personnel and assets. The information must be delivered to the Air Force Weather enterprise to use as part of a comprehensive and ongoing environmental analysis and mission impact assessment.

Previously procured commercial systems require improvements to satisfy demanding military requirements. The Air Force requires improvements in the areas of reliability (software and hardware), maintainability (field-replaceable/upgradeable standard parts), ruggedization (high probability of surviving military transportation, handling by a forklift on a standard pallet, with each packed container hand-portable by a maximum of two persons), and component costs. The Air Force also desires an increase in power to collect weather data over an increased area. The weather data should be compatible with NEXRAD Level III specification and readable by standard weather analysis software, provide for remote analysis of the health of the system, provide, as needed, for the operational configuration and tuning of the system by on-site personnel, and provide an intuitive user interface.

This solicitation requests a comprehensive report researching the state-of-the-art in Doppler weather radar with a focus on the key areas of reliability, robustness, weight, maintainability, compatibility with existing DoD IT infrastructure, ruggedization, transportability, quick setup and operational capability once in the field; and requests the production of an innovative portable Doppler radar solution that combines existing state-of-the-art technology to exceed current Air Force portable Doppler radar capabilities, demonstrates the ability to realize the proposed solution in a low-rate production environment, and provide recommendations on logistics and maintenance that favor an affordable, efficient maintenance process.

Assuming the study in Phase I is successful, Phase II and III will be used to design, develop, deliver, and demonstrate a new portable Doppler radar that exceeds current Air Force capability and is a clearly preferable solution to the end user.

The AFWA will draw upon sensors other than the Portable Doppler Radar (PDR) to compose a complete picture of the weather situation. In addition to augmenting PDR for weather, the PDR can also contribute to the air picture by providing hard target search and track information as consistent with the trend in domestic and other military radar applications.

PHASE I: Research applicable technologies related to Doppler weather radar, processing data from the radar sensor, delivering the data over the DoD IT infrastructure. Conduct antenna trade studies between mechanical and electronic scan, single versus dual polarization, single versus dual frequency, single versus multiple faces, and multifunction to include air surveillance versus single weather detection.

PHASE II: Design, develop, deliver, and demonstrate a physical and electronic brassboard-level prototypes of a Doppler radar solution that was identified in Phase I. Assembly, disassembly and transport to be demonstrated through production representative article physical mock-up. Users will be brought in to provide feedback on operational suitability.

PHASE III: Finalize the design and development of the proposed solution and demonstrate preparedness for low rate production. Produce production representative prototype and demonstrate performance. Users satisfaction with the finalized radar is paramount.

REFERENCES:
1. Current product solution is the EWR Weather Radar Systems model E700XD.

2. Refer to DoD 8570.1 for information assurance accreditation requirements. Other DoD and Air Force directives may apply.

3. Technical Requirements Document - Portable Doppler Radar, 27 May 2009.

KEYWORDS: portable, Doppler, radar, weather

AF151-140 This topic has been removed from the solicitation.

AF151-141 TITLE: <u>LWIR Narrow-Band Spectral Filters</u>

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US

Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: To develop narrowband, patterned optical filters in the longwave infrared (LWIR) spectral region for imaging spectrometry applications.

DESCRIPTION: Hyperspectral imaging, an emerging remote sensing technology with numerous military and civil applications, is traditionally performed using a dispersive (prism or grating) reimaging system with a slit and focal plane array (FPA) at the conjugate image planes. In the longwave infrared (LWIR), this optical subsystem must be cooled to reduce instrument self-emission to acceptable levels. Coupled with the size of the imaging spectrometer, this cooling requirement can result in size, weight, and power (SWAP) demands that preclude the insertion of LWIR imaging spectrometry into practical systems, especially those intending to be deployed within gimbaled systems and on small airborne platforms. An alternative approach is to perform the field-dependent spectral filtering completely on the FPA using narrowband, patterned filters whose center wavelength varies from one array element to the next. Various system concepts have been investigated based on such on-chip filters as described in the related references; however, a method for producing such filters with acceptable performance does not currently exist.

The primary challenge is to produce bandpass LWIR filters with on the order of 60 nm spectral resolution over the 7.5 to 13.5 micron spectral range with a center wavelength that changes along at least one dimension of the FPA. The change in center wavelength between adjacent detector elements (on the order of 20 to 40 micron pitch) is on the order of the spectral resolution. To maintain instrument sensitivity, the filters must exhibit high transmission (70 percent or higher) and operate properly with imaging systems on the order of f/3 as a threshold requirement, and with the objective f/1. Concepts supporting direct deposition of filters on FPA, or even inserting the narrowband filtering in the detector response, are of interest; however, the baseline concept is for a patterned filter on an infrared-transmitting substrate that can be mounted directly in front of a cryogenically-cooled (40-65 K) infrared FPA.

There will be no need for government materials, equipment, data, or facilities in the initial phase of this research.

PHASE I: Perform analysis of potential spectral filter designs and select optimum technical approach. Develop preliminary design and perform detailed analysis.

PHASE II: Complete detailed design and manufacture prototype filter compatible to a government-specified FPA pixel size/pitch. If full the LWIR bandwidth cannot be fabricated within limits of SBIR funding, develop a demonstration prototype that will cover a portion of the bandwidth.

PHASE III: Complete prototype hardware that will cover entire LWIR bandwidth. Military applications: Hyperspectral sensing at lower light levels and/or longer ranges than current systems. Commercial applications: Lower cost hyperspectral sensors for agriculture, land use, search/rescue, and homeland security.

REFERENCES:
1. James W. Jeter, Karl R. Blasius, "Wedge spectrometer concepts for space IR remote sensing," Proc. SPIE 3756, 211-222 (1999).

2. U.S. Patent 5,760,899 "High-sensitivity multispectral sensor" (1998).

KEYWORDS: Hyperspectral, LWIR, spectral filters, F-number, spectrometer

AF151-142 TITLE: <u>Avionics Access Points and Connection Protection</u>

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of

sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Design and develop a methodology and tool to verify trustworthiness of critical avionics embedded software and identify methods to mitigate vulnerabilities to ensure mission success.

DESCRIPTION: Cyber threats against our weapon system airframes and related systems are forcing an urgent need to protect our aircraft systems from cyber attacks and exploitation. Our most current kinetic weapon systems were not designed for considering the cyber security threat, and resilience thereof. Current information assurance (IA) and safety certifications focus on operational ranges and known fault conditions, but no effort is made to counter the intelligent cyber attacks that have been executed in the past or anticipate possible threats by a sophisticated and well-resourced adversary. Each airframe contains numerous electronic line replaceable units (LRUs) that are connected to other LRUs and avionics subsystems. These weapons system components should be secure when delivered, however they are susceptible to cyber attacks because of substandard coding methods which include the lack of software vulnerability scanning and correction at the engineering level. Adversaries can exploit these vulnerabilities within the systems via various connection points during maintenance operations, and other software/hardware/firmware updates due to mission requirements.

Current processes to identify system vulnerabilities are ad-hoc, and labor intensive, they require specialized knowledge to identify and assess likely attack vectors. Additionally, methods for conducting an operational impact analysis have not been developed or matured to determine how these weaknesses impact the mission. This methodology and supporting tools are required to analyze both the logical and physical avionics architecture and use this information to drive a protection solution. This methodology must consider and identify how the subsystems are interconnected as well as access points to those systems through which support elements (e.g., maintenance aids, data loaders) are connected. Lastly the process must support identification of the possible exploitation of the systems and connection points and determine the operational impact to the weapon system; with this data a risk management process can define controls and countermeasures to limit or eliminate the threat. The overall goal for this effort is to mitigate vulnerabilities through access points by 80 percent through authentication, input validation, and employ protection techniques while reducing security susceptibilities by 80 percent associated with mission planning, maintenance, loader, and test equipment, etc.

PHASE I: Conduct analysis of systems and services to determine the assets with the highest operational impact. Design a methodology and framework for vulnerability characterization of avionics systems as well as identification of mitigation strategies against potential cyber attacks. Provide a proof-of-concept design and architecture to demonstrate the feasibility of methodology and framework.

PHASE II: Based on the results from Phase I, refine and extend the prototype system design to a full software suite to automate cyber vulnerability characterization and recommend appropriate mitigation techniques for avionics LRUs. Conduct a vulnerability characterization and trustworthiness assessment for selected aircraft avionics, at multiple support levels. For software-based mitigation methods, prepare functional and logic diagrams and code. Demonstrate the effectiveness of the resulting capability.

PHASE III: The proposed framework, methodology, and tool suite should be enhanced to support vulnerability identification and mitigation of both commercial and military applications.

REFERENCES:
1. Baldwin, Kristen. (2009), “Systems Security Engineering: A Critical Discipline of Systems Engineering”, Vol. 12, Issue 2, International Council on Systems Engineering.

2. DoD 8500.01 - Cybersecurity.

3. DoD 8510.01 - Risk Management Framework for DoD IT.

KEYWORDS: avionics, access point, connection protection, cyber attacks, system trustworthiness

AF151-143 TITLE: High Speed Non-mechanical Beam Steering for Coherent LIDAR/LADAR

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop and demonstrate revolutionary technologies for non-mechanical steering of coherent LIDAR/LADAR technologies, such as Synthetic Aperture Ladar (SAL) for target acquisition, identification, and tracking.

DESCRIPTION: Synthetic Aperture LADAR (SAL) is an imaging sensor technique that provides long-range optical images using the time of flight measurement from the platform and tracking the phase of the return signal over time to produce a synthetic image. SAL operates according to the same principles as Synthetic Aperture Radar (SAR), enabling the capture of images with a synthetic aperture much larger than the physical aperture, and resulting in high resolution images at longer ranges than possible with a physical aperture. Compared to SAR, SAL operates at wavelengths less than 1/1000 that of SAR, providing much higher resolution and can provide images with the fidelity needed for target identification. Because SAL operates at wavelengths similar to visible wavelengths, images from a SAL system are readily interpretable by humans without training.

Non-mechanical beam steering (NMBS) is a technology that provides the ability to direct a laser beam without physical movement of the optical elements. Although NMBS techniques have been demonstrated to steer optical imagery for conventional focal plane imagery, NMBS has not been shown to operate with a SAL system. NMBS offers similar advantages to a SAL sensor as it does to direct detection ladar, such as reduced weight, random access to steering directions, and expanded field of view. Due to long ranges and the correspondingly long time of flight, there is the potential for SAL systems to handle multiple look directions simultaneously. In addition, because of the long ranges that SAL is expected to operate at, the ability of NMBS to provide high speed beam stabilization is an additional benefit that could be realized.

To date, the most effective NMBS systems operate using liquid crystal devices to modify the phase of the beam to steer the beam. While in direct detection ladar systems, the phase changes are not a significant concern, in a coherent ladar, such as SAL, the effect of the NMBS system on the phase is critically important. To date current NMBS devices have not demonstrated compatibility with coherent ladar systems.

Commercial application of a NMBS with SAL sensors would provide similar benefits to military systems.

The goal of this effort is to demonstrate a NMBS technology that is compatible with a SAL sensor, which could be used in a target pod to support long range target identification. The NMBS should show capability to steer a SAL system with minimal impact to performance. The primary SAL wavelength of interest is 1.5 micron, however operations from 1 to 2 microns can be considered. The steering system should be capable of scaling to 15 cm apertures. The steering system should be capable of steering 45 degrees off-boresight. Continuous steering is preferred, but not required. In the case of a step steering system, the steering increments should be no more than 1 degree. Steering efficiency is important and should be greater than 80 percent (power out/power in). Switching speeds should be greater than 1 kHz. The overall system should demonstrate compatibility with a SAL system with steering on both the receive and transmitter paths because phase noise on the transmitter could directly translate to phase noise on receive. The technology demonstrated must show traceability to a pod environment, power < 100 Watts, weight < 5 kg, and < 4 L of volume.

Government materials, equipment, data or facilities are not necessary.

PHASE I: In this initial phase, device concepts will be developed, evaluated, and computer modeled. Design challenges and trade-offs will be tabulated and areas in need of additional research and development will be identified. Projections will be made for the impact of the device on SAL performance. Preliminary designs should be developed for Phase II.

PHASE II: Prototype devices will be constructed and tested for beam steering efficiency and compatibility with SAL will be tested. Analysis will be conducted on the nature of any adverse effects on SAL and mitigation strategies will be developed. Iteration on designs and improvements will be made as the production process is refined and preliminary designs for a phase III device should be made.

PHASE III: A refined version of the design will be built, showing the SAL performance, and steering efficiencies. Current manufacturing process will be evaluated and refined to improve yield while reducing cost. A demonstration 15-cm aperture device will be built and tested with a SAL system.

REFERENCES:
1. Optical Phased Array Technology, Paul F. McManamon et. al., Proceedings of the IEEE, Vol. 84, No. 2, February 1996.

2. Numerical Analysis of Polarization Gratings using Finite-difference Time-domain Method, Ch Chulwoo and Michael J. Escuti, Physical Review A, Vol 76, No. 4, 043815, 2007.

3. Resolution Enhanced Sparse Aperture Imaging, Miller et. al, IEEE Aerospace Conference Proceedings, V 2006, 2006 IEEE Aerospace Conference, 2006, 1655904.

4. Wide-Angle, Nonmechanical Beam Steering Using Thin Liquid Crystal Polarization Gratings, Jihwan Kim et. al., Advanced Wavefront Control: Methods, Devices, and Applications VI, Proc. of SPIE, Vol. 7093, 709302, (2008).

5. Laser Radar Systems and Techniques, C. G. Bachman, Artech House, Boston, 1979.

KEYWORDS: optical phased array, 3D, LADAR, flash imaging, non-mechanical, beam steering, image steering, mosaic, mosaic imaging, tiled, tiled imaging, LIDAR, FLIR, MWIR, SWIR, polarization

AF151-144 TITLE: <u>Electronic Warfare Circumvent and Recover</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Design/demonstrate a circumvention and recovery scheme that can sense EW weapon induced effects on electronics, mitigate before damage to the logic and/or hardware is incurred and resume operations when levels have reduced to safe operating levels.

DESCRIPTION: With the increase in the technology readiness level of offensive electronic warfare (EW) weapons, blue force weapon systems require schemes to mitigate vulnerabilities to these types of weapons. Shielding and hardening circuits can be effective but can be costly, adding size/weight and reduced performance. An alternative that has been used with success in nuclear-induced environments are circumvention and recovery (C&R) schemes. However, these schemes depend on sensing ionizing radiation which may not be present when a system is targeted by an EW weapon. The Air Force is interested in applying a protective solution/action to various sensitive electronics and is looking for novel ways to detect possible damaging effects and respond accordingly prior to upset and possibly mission failure. The sensor needs to be able to detect and survive a wide variety of EW weapons effects, including, but not limited to HPM, HEL, SREMP, SGEMP, RF jamming, etc. The sensor would need to be able to operate in standard atmospheric environments that USAF weapon systems are subjected to. Once a weapon-induced environment is sensed above appropriate thresholds, the system can respond prior to upset by verifying a correct operating state, protecting the verified state, reloading the verified state and resuming operations when the weapon effect falls below the appropriate thresholds. Bidders should consider a wide variety of robust sensing and C&R possibilities while placing a high emphasis on novelty so it can be tailored to emerging threats.

PHASE I: Identify candidate architectures/schemes/technologies to sense and mitigate various EW weapons effects and prevent damage to the operating logic. Perform/document trade studies on the proposed schemes to determine the most favorable candidate. Develop plans to build and demonstrate the identified candidate.

PHASE II: Build and demonstrate the identified candidate from Phase I. Perform testing to show its effectiveness against a representative set of EW effects. Document design and report on testing results.

PHASE III: Military Application: Can be adopted to any system expected to be exposed to EW weapons in the battlefield. Commercial Application: Can be used in any field storing or operating with sensitive data such as the Smart Grid, Servers containing PII or similar, financial networks, etc.

REFERENCES:
1. M. Skolnik, "Radar Handbook," McGraw-Hill Professional Publishing, 1 January 1990.

2. D. Adamy, "EW 101: A First Course in Electronic Warfare," Artech House, 1 February 2001.

3. D. Adamy, "EW 102: A Second Course in Electronic Warfare," Artech House, 20 August 2004.

4. Section 6.4, http://fas.org/irp/threat/mctl98-2/p2sec06.pdf.

5. Section 6.7, http://fas.org/irp/threat/mctl98-2/p2sec06.pdf.

KEYWORDS: circumvent, recover, electronic warfare, sensors, detection, surety

AF151-145 TITLE: Waveform Agile, Low-cost Multi-function Radio Frequency ISR in Contested Environment

TECHNOLOGY AREAS: Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop innovative waveforms and exploitation algorithms for concurrent synthetic aperture radar (SAR) and ground moving target indication (GMTI) in contested environment.

DESCRIPTION: Global integrated intelligence, surveillance, and reconnaissance (GIISR) is one of the service core functions of the U.S. Air Force. GIISR will provide battlefield information to the warfighter at any weather condition in real-time. Experts believe unauthorized users can hold our intelligence, surveillance, and reconnaissance (ISR) assets at risk and force us to operate at sub-optimal standoffs. Further, inexpensive electronic attack systems can limit our ability to collect reliable ISR from mono-static platforms. Hence, to address these onerous technical challenges for contested/anti-access area denial (A2AD) environment, the Air Force must develop affordable, low-cost ISR systems with advanced exploitation capabilities. In general, future ISR systems must be designed so that unauthorized users cannot penetrate to downgrade our ISR capabilities at any critical chain (transmit, receive, and processing) of operation. Our transmit signals must be designed in such a way that an enemy cannot see our presence.

Recently, researchers have developed theoretical foundation for spread spectrum coded linear frequency modulation (LFM) transmit signal that has potentials for solving some of the above mentioned technical challenges of the contested environment [1-2]. Some of the characteristics of these signals are: (a) inherit properties of direct sequence spread spectrum and LFM waveforms, (b) remain almost orthogonal on both transmit and receive, and (c) can hide while operating in adversaries environments. In addition, when properly processed, two important benefits of these signals are: (a) can provide exploitation capabilities that LFM waveforms exhibit (i.e., Doppler tolerant) and (b) can achieve high resolution imaging capability to separate a weak target that is close to a strong target. Other approaches on waveforms design and exploitations can be found in various literatures [3-5].

We are seeking sensor technology development to accomplish both (1) transmit signal design and (2) exploitation algorithms for simultaneous SAR and GMTI processing. This technology should advance the state-of-the-art and be effective in the A2AD environment; in particular, our signal should not be corrupted by the other users so as to reduce the effectiveness of the surveillance systems. Operating environment to be focused on is contested region but not limited to other scenarios. Performance measures to include are improved signal to clutter and noise ratio, ultra high resolution to discern a weak target close to a strong target, and shorter time for both SAR and GMTI exploitation.

The emphasis of this research will be developing waveforms and exploitation algorithms for affordable ISR systems to provide tactical edge in the A2AD/contested environment. We are interested in experimenting proposed waveforms (in hardware) and using these to develop joint SAR and GMTI exploitation algorithms. If implemented successfully, the key benefits to the warfighters will be: (1) transmit signals can hide in adversaries environment but enable ISR objectives and (2) solve the joint SAR and GMTI problem without complexities associated with reconfiguring the radar systems for SAR or GMTI mode. Teaming with a prime contractor is encouraged. No government funded equipment or data will be provided. The contractor will be responsible for the performance evaluation of the waveforms and the exploitation algorithms. No Air Force Research Laboratory facilities will be provided. Government will define the performance parameters. The contractor shall use simulated data (as part of the solution to this research problem) for performance evaluation.

PHASE I: Research and develop affordable and practical radar waveforms to address contested environment ISR. Using these waveforms, develop signature exploitation concept for concurrent SAR and GMTI for multiple moving and stationary targets detection, geolocation, and tracking. Develop initial technology transition plan and business case analysis.

PHASE II: Implement (hardware and software) the waveforms and signal processing concepts proposed in Phase I for target detection, geolocation, and tracking of moving targets for contested environments. Develop software toolbox to fully characterize performance bounds of the proposed exploitation algorithms. Refine technology transition plan and business case analysis.

PHASE III: Qualify and insert proposed technology into an acquisition program.

REFERENCES:
1. U. Majumder, M. Bell, M. Rangaswamy, "A Novel Approach for Designing Diversity Radar Waveforms that are Orthogonal on Both Transmit and Receive," Proceedings of IEEE Radar Conference, 2013.

2. U. Majumder, M. Bell, M. Rangaswamy, "Diverse, Waveforms and Processing Techniques for Joint GMTI and SAR Exploitation," to appear in Proceedings of IEEE Radar Conference, 2014.

3. M. Davis, R. Kapfer and R. Bozek, Common Waveform for Simultaneous SAR and GMTI, Proceedings of IEEE Radar Conference, 2011, Kansas City, MO.

4. J-C. Guey., and M. Bell. “Diversity Waveform Sets for Delay-Doppler Imaging,” IEEE Transaction on Information Theory, Volume 44, No.4, July 1998.

5. M. Minardi and E. Zelnio. Comparison of SAR based GMTI and standard GMTI in a dense target environment, Proceedings of SPIE 6237, Algorithms for Synthetic Aperture Radar Imagery XIII, 62370X, May 17, 2006.

KEYWORDS: synthetic aperture radar (SAR), ground moving target indication (GMTI), intelligence surveillance reconnaissance (ISR), geolocation, orthogonal waveforms

AF151-146 TITLE: Robust and Reliable Exploitation for Ground Moving Target Detection, Geolocation and Tracking Using Synthetic Aperture Radar

TECHNOLOGY AREAS: Battlespace

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop innovative theory and quantitative performance bounds for detection, geolocation, and tracking of moving targets using synthetic aperture radar (SAR).

DESCRIPTION: Ground moving target indication (GMTI) processing is a critical technology for persistent, all-weather global integrated intelligence, surveillance, and reconnaissance (GIISR). GMTI processing includes detection, geolocation, and tracking of multiple moving and stationary targets. In recent years, SAR has been used in intelligence, surveillance, and reconnaissance (ISR) platforms due to all-weather exploitation, video SAR formation, and long-range coverage. Unlike conventional radar, SAR can provide video of the interrogated scene and detection and tracking capabilities. In addition, using a SAR system, a target could be detected without a minimum detectable velocity (i.e., detection of move-stop-move target). Furthermore, SAR-GMTI processing can be accomplished using a single phase center/single channel. However, multiple moving targets detection, geolocation, tracking, in complex environment is a challenging problem. This is due to the fact that moving targets" signature Doppler shift and smear because of velocity of the targets and radar. Moreover, noise of the operating environments and clutter sources add complexity to detect and track targets. Hence, the goal of this research is to develop a unified theory for multiple moving targets detection, geolocation, and tracking in complex, heterogeneous clutter environments.

Researchers developed theories and algorithms to address the GMTI processing [1-5]. Among different techniques, scientists developed a strategy to focus the energy of a moving target so that it could be detected and tracked. However, geolocation problems are left unresolved or operating environments with multiple targets or weak targets (i.e., low radar cross section targets) have not been considered for these solutions. Some researchers have implemented “ad hoc” techniques (i.e., GMTI algorithms) for target detection and tracking that work on some specific data set only.

The emphasis of this research will be fundamental understanding of moving target phenomenology under SAR and incorporating those findings for GMTI algorithm development. First, research needs to be conducted to fully understand the parameters that influence defocussing/smearing of moving targets’ signature. Second, we have to investigate the influence of noise and clutter on multiple moving targets detection, geolocation, and tracking. Third, we have to examine waveforms’ role for targets detection. Fourth, we need to evaluate different tracking algorithms and select the one that will perform the best for a given operating environment. Fifth, we may need to incorporate prior information of the interrogated scene for geolocation accuracy. Computational costs associated with real-time execution of the proposed algorithms should be fully analyzed. The ability to integrate these areas into a unified systems theory prototype to allow system trade studies may also be needed. By addressing the above mentioned technical barriers and developing a system trade space analysis capability, we may reach a comprehensive solution and unified theory for GMTI processing that is vital for improving performance of modern persistent ISR systems. We are interested in experimenting proposed algorithms to various radar operating environments that include air-to-ground or space-to-ground. Frequency parameters for radar could be ranging from UHF to Ka band. For air-to-ground operation, 45 degree elevation angle will be considered. For Phase I and Phase II research efforts, no measured data (or other government materials and equipment) will be used or provided; Matlab or other software will be used to develop simulated data and algorithms.

Teaming with a prime contractor is encouraged. No government funded equipment will be provided.

PHASE I: Develop innovative systems theory prototype with meaningful components and system performance metrics for multiple moving and stationary targets detection, geolocation, and tracking. Quantify effects of operating environments and system parameters on performance of the proposed algorithms. Develop a technology transition plan and initial business case analysis.

PHASE II: Implement Phase I solution for target detection, geolocation, and tracking of moving targets in complex environments. Develop software toolbox to fully characterize performance bounds of the proposed algorithms. Apply algorithms to appropriate measured data (e.g., Air Force Research Laboratory Gotcha Radar). Compare performance on measured and simulated data. Refine technology transition plan and business case analysis.

PHASE III: Qualify and implement algorithms on acquisition platforms.

REFERENCES:
1. Gregory E. Newstadt, Edmund Zelnio, Leroy Gorham, and Alfred O. Hero III "Detection/tracking of moving targets with synthetic aperture radars," Proc. SPIE 7699, Algorithms for Synthetic Aperture Radar Imagery XVII, 76990I, April 18, 2010.

2. M. J. Minardi, L. A. Gorham, and E. G. Zelnio, "Ground moving target detection and tracking based on generalized SAR processing and change detection (Invited Paper)," Proc. SPIE 5808, Algorithms for Synthetic Aperture Radar Imagery XII, 156, June 14, 2005.

3. Mehrdad Soumekh, “Moving target detection and imaging using an X band along-track monopulse SAR,” IEEE Transactions on Aerospace and Electronic Systems, Volume 38, Issue 1, pp. 315-333, January 2002.

4. J.R. Fienup, “Detecting moving targets in SAR imagery by focusing,” IEEE Transactions on Aerospace and Electronic Systems, Volume 37, Issue 3, pp. 794-809, July 2001.

5. Jen King Jao, “Theory of Synthetic Aperture Radar Imaging of a Moving Target,” IEEE Transactions on Geoscience and Remote Sensing, Volume 39, Number 9, pp. 1984-1992, September 2001.

KEYWORDS: synthetic aperture radar, SAR, ground moving target indication, GMTI, intelligence surveillance reconnaissance, ISR, geolocation

AF151-147 TITLE: <u>Multiple-Global Navigation Satellite Systems (GNSS) Compatible with Military Global Positioning System (GPS) User Equipment (MGUE)</u>

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual

use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop an open-signal Global Navigation Satellite System (GNSS) receiver engine to enhance the resilience of military Global Positioning System (GPS) user equipment.

DESCRIPTION: Anticipating future strategic technical needs, this SBIR seeks low-risk/low-cost system concepts for the use of multiple Global Navigation Satellite System (GNSS) signals to improve the resilience of the Military GPS User Equipment (MGUE). The objective is to develop and implement methods that allow for the utilization of the open-signal GNSS signals to generate Position Navigation and Timing (PNT) with improved integrity, authentication and availability compared to commercial off-the-shelf (COTS) GNSS offerings. When integrated with MGUE, this must occur without compromising the current security and information assurance of MGUE [1].

An example of a system concept for processing the GNSS signals with MGUE could be to use a “GNSS Engine” that could be “bolted-on” to the “MGUE Engine” on a host application system. The host system using an external application processor would blend the same observables from both engines to produce a resilient GNSS and MGUE PNT solution.

In recent years, interest has grown in developing useful anti-spoof techniques for non-military use. Researchers in the United States and abroad have conducted research in this area, yielding a significant amount of open source literature on the topic. Examples of suitable techniques include signal power monitoring, reasonability checks, Receiver Autonomous Integrity Monitoring (RAIM) techniques, statistical evaluation, and direction of arrival measurements. Techniques should be evaluated in terms of complexity, processing requirements, additional hardware (HW) (e.g., multi-element arrays) required, ease of modification, suitability for different applications (e.g., smartphone or avionics receiver), and effectiveness against different types of attacks.

The goals for such a hybrid MGUE-GNSS system would be dependent upon the representative military host platform capability; however the following suggestions should guide the development effort:
1. Projected power consumption increase due to resiliency functionality is less than 10 percent over the baseline MGUE capability.
2. Size and weight impact to the host application system does not adversely impact the user or drive integration costs.
a. For handheld PNT systems, size and weight increase is kept below 15 percent of the baseline.
b. For munitions and aviation platforms, size should be constrained to form factors of existing line replaceable units and increased weight should not adversely affect the center of gravity of the platform.
c. Antenna requirements should take into account existing antenna mounting, depth and siting locations for the host platform to minimize integration cost.
3. Impacts to user tactics, techniques and procedures must be clearly identified.
4. Requirements for external communications or networking to facilitate resiliency should fit into existing concepts of operation for similar military systems.

Government furnished equipment (GFE) in the form of an FPGA-based GPS and GNSS development environment will be available in Phase II.

PHASE I: Conduct comprehensive comparative assessment of simple anti-spoof techniques suitable for GNSS-MGUE implementation, evaluate complexity, processing requirements, additional HW, ease of modification, suitability for various end user applications, and effectiveness against spoofing attacks. Consider operation with typical anomalies as multipath, satellite geometry, and atmospheric conditions.

PHASE II: The most promising system design would be prototyped in hardware utilizing equipment of the contractor’s design, choice or the GFE.

PHASE III: The concept would be demonstrated and validated by integrating the demonstration hardware on a representative military host platform. Commercialization would yield GNSS COTS add-on products or licenses to MGUE vendors.

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KEYWORDS: GPS, Multiple-GNSS, MGUE, integrity, authentication, anti-spoofing

AF151-148 TITLE: Space Qualifiable Radiation Hardened Compound Semiconductor Microelectronic Device Technology

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop and demonstrate high performance compound semiconductor microelectronic devices suitable for insertion into space application.

DESCRIPTION: The Air Force is seeking a novel technique to maximize the level of component integration in their satellite communications payloads. The technique should be able to monolithically integrate microelectronic devices constructed with dissimilar semiconductor materials on the same substrates, thus significantly reducing parts count. The technique should lead to compact subsystem-level design with improved functionality and overall performance without compromising reliability and performance characteristics of individual components. This topic should benefit various space programs where continuing demand to increase power handling capability and bandwidth is met in addition to stringent size, weight, and power (SWAP) requirements.

Of a particular interest is to monolithically integrate InGaAs HEMT technology with other technology such as GaN HEMT on the same substrate. Since each technology has its own advantages as well as disadvantages, this topic is seeking a novel approach to maximize advantages of different technologies, i. e. low noise/high speed characteristics for InGaAs HEMT technology and high power/high voltage characteristics for GaN HEMT technology.

The ultimate goal of this topic is to develop a space qualifiable compound MMIC that can lead to construction of low noise/high speed circuits based on InGaAs HEMT technology monolithically integrated with power amplifiers based on GaN HEMT technology on the same substrates. Packaged modules housing these parts should be readily integrated into satellite payloads to provide reliable satellite communications over a typical 12 year design life. Device designs should be for Ka band, (30 – 31 GHz) and for Q band (43.5 – 45.5 GHz). Goals include: the noise figure less than 2.5 dB with the associated gain of better than 20 dB for low noise amplifiers constructed with InGaAs HEMT technology and the gain greater than 20 dB, P1dB of 35 dBm, Psat of 40 dBm for power amplifiers constructed with GaN HEMT technology in addition to operating temperature range - 40 degrees C to + 85 degrees C and total ionizing dose > 300 krad (Si).

PHASE I: Develop concepts to integrate different compound semiconductor device technologies within an integrated circuit. Document all challenges, i.e., thermal, fatigue, losses, new degradation mechanisms, and packaging tailored to the proposer"s selected fabrication (foundry) for Phase II. Develop designs, models and simulations of integrated test structures that address resolution of the key challenges.

PHASE II: Demonstrate and validate Phase I concepts through fabrication, modeling, and simulation and characterization of the appropriate test structures and circuits. Identify end of life degradation mechanism(s) and perform preliminary accelerated life-testing. Execute short-term PCM-level accelerated life-tests to demonstrate the viability of technology. Carry out radiation susceptibility testing and analysis for total dose and heavy ions of the integrated part.

PHASE III: Develop high speed/high modules containing integrated circuits meeting communication satellite requirements such as Advanced EHF and its successors that will benefit from this technology. Commercial terrestrial fiber optic and wireless telecommunications will also benefit.

REFERENCES:
1. T. E. Kazior, et al., “High performance mixed signal and RF circuits enabled by the direct monolithic heterogeneous integration of GaN HEMTs and Si CMOS on a silicon substrate,” Compound Semiconductor Integrated Circuit Symposium (CSICS), pp. 1-4, 2011.

2. J. W. Chung, et al., “Seamless on-wafer integration of GaN HEMTs and Si(100) MOSFETs,” Device Research Conference (DRC), pp. 155 – 156, 2009.

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KEYWORDS: compound semiconductor, microelectronic devices, InGaAs HEMT, GaN HEMT, monolithic integration, space qualification

AF151-149 TITLE: Ka-Band and Q-Band Low Noise Amplifiers

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop low noise amplifiers in Ka-band and Q-band for SATCOM and point-to-point digital radios.

DESCRIPTION: Signal noise poses a significant challenge to long-distance satellite communications, impacting bit error rates, the level of transmitter radiated power required to close the link, and, indirectly, the payload size, weight and power. The 2dB Noise Figure (NF) has been demonstrated at Ka-Band and Q-Band using InP HEMT and mHEMT processes. The purpose of this topic is to develop innovative state-of-the-art low-noise amplifiers (LNA) using advanced low noise Monolithic Microwave Integrated Circuits (MMICs) processes to demonstrate compact producible Ka-band and Q-band LNAs for space and terrestrial applications. This topic is intended to support research exploring the best approach and process for achieving low noise and high gain with optimum linearity (measured by the output third-order intercept point, or OIP3, across the frequency of operation) and demonstrate the level of performance that can be achieved in low-noise amplifiers for satellite application at Ka-Band (27.5 to 31.0 GHz) and Q-Band (43.5-47 GHz). Goals include NF <2.0 dB at Ka-Band, NF<2.0 dB at Q-Band, small signal gain >25 dB, input and output return loss less than -10 dB, low power consumption (<500 milliWatts), high linearity (IP3 and OIP3 > 10 dBm), operating temperature range -20 to +70 deg C. The total dose radiation tolerance goal is 300 krad(Si) for the Ka-Band LNA and 1 Mrad(Si) for the Q-Band LNA. Characterization of noise performance at cryogenic temperatures would also be of interest.

PHASE I: Develop a Ka-band and Q-Band MMIC designs meeting objectives identified above. Validate through modeling and simulation where appropriate.

PHASE II: Fabricate MMIC designs for Ka-band and Q-band. Characterize for amplifier noise, gain, linearity, and power consumption under typical operating conditions.

PHASE III: Military low-noise amplifiers will support WGS and AEHF follow-on satellites and point-to-point digital radios. Commercial low noise amplifiers under this effort will directly benefit commercial communication networks in Ka-band and Q-band frequency bands.

REFERENCES:
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KEYWORDS: Ka-band, Q-band, LNA, MMIC

AF151-150 TITLE: Ka-Band Efficient, Linear Power Amplifiers for SATCOM Ground Terminals

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of

sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop efficient, linear Ka-band solid-state power amplifiers (SSPAs) for mobile low-cost ground terminal applications.

DESCRIPTION: Efficient, high-power performance is required to support low-cost terminals for future military satellite communications (SATCOM) ground terminals. Power amplifier efficiency translates to the terminal's DC power consumption requirements, as well as additional hardware/structures to address corresponding cooling requirements. Reductions in the size, weight and power (SWaP) are critical to lowering ground terminal power consumption, footprint and cost. Innovative linear-efficient circuit techniques, in combination with high-performance power technologies, have the potential of producing linear-efficient SSPAs to meet this low-cost terminal need. Improved power amplifier efficiency may be achieved with solid-state power technologies such as gallium nitride (GaN), while linear-efficiency may be addressed with techniques such as envelope tracking. Selected approaches should also address low-loss power combining towards the demonstration of a fully integrated SSPA. The overall approach should meet or surpass current state-of-the-art performance, while providing cost, size, weight and power (CSWaP) improvements. Therefore, required performance for the Ka-band SATCOM SSPA includes power-combined linear-efficient output greater than 70 watts over 30.0-31.0 GHz, with power-added efficiency greater than 35 percent. Additional performance requirements include linearity consistent with Quadrature Phase Shift Keying (QPSK), as well as with 12/4 Quadrature Amplitude Modulation (QAM), operation. Performance trades may include wider band 29.0-31.0 GHz performance to include commercial 29.0-30 GHz (ground terminal) and 29.5-30 GHz (airborne terminal) applications. Further, the selected power amplifier approach should support reliable operation over the -40 degrees to +80 degrees Celsius operating temperature range.

PHASE I: Concept design and circuit simulations of the linear-efficient Ka-band monolithic integrated circuit (MMIC) power amplifier based on a suitable, high-performance millimeter-wave transistor process, as well as the design of the higher-level SSPA. Potential bandwidth and CSWaP advantages should be considered.

PHASE II: Fabrication of the linear-efficient prototype Ka-band power amplifiers (MMICs, power combiner, integrated SSPA) according to Phase I design. Characterization of the power amplifier and SPPA for linearity, output power, and efficiency under typical signal and environmental conditions.

PHASE III: Military high power amplifier applications include ground terminal Ka-band communications uplink electronics for Wideband Global SATCOM (WGS). Commercial Ka-band high power amplifier applications include ground/airborne electronics where millimeter-wave power sources are required.

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KEYWORDS: Solid State Power Amplifier, millimeter-wave amplifiers, satellite communications, Ka-band, gallium nitride, envelope tracking

AF151-151 TITLE: Integrated Photonic Optical Circulator

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop wide-bandwidth, high-isolation optical circulator devices compatible with emerging photonic integrated circuit processes in order to enable optical signal processing architectures that require nonreciprocal waveguide elements.

DESCRIPTION: Radio Frequency sensor performance can benefit from the use of wide bandwidth, high frequency photonic signal processing techniques, especially as the development of Photonic Integrated Circuits (PIC) realize reductions in cost, size, weight and power that enable transition opportunities to DoD systems. Key to the development of useful PIC based signal processing techniques is the availability of nonreciprocal components such as the optical isolator and circulator that separate optical signals traveling in opposite directions. Optical circulators are commonly used to drop an optical channel from WDM systems and require a break in optical symmetry when the light passes through in the opposite direction. There is a need to optimize nonreciprocal waveguides that can be included into the emerging standardized PIC fabrication processes that include a range of devices such as low loss interconnect waveguides, power splitters, filters, as well as active optical modulators, amplifiers, lasers and photodetectors. Previous attempts at demonstrating nonreciprocal PIC waveguide elements have focused on incorporating magneto-optical materials into the waveguide structures using micro-optics, heterogeneous as well as monolithic approaches. Performance to date has been limited isolation to below 25 dB whereas isolation of 30-40 dB is required in order to find application in DoD systems. Challenges that have limited performance include waveguide birefringence, fabrication tolerances, garnet/semiconductor mismatch, and optimized interfaces. This program seeks novel approaches coupled with advanced technologies to enable the development of heterogeneous and/or monolithic PIC nonreciprocal waveguide technique for achieving optical circulators having wideband (>30 nm), high isolation (40 dB) between ports 1 and 3 and low loss (<1dB) between ports 1 & 2 and 2 & 3. Polarization insensitivity and small component footprint is also desired.

PHASE I: Phase I will investigate conceptual designs for an integrated photonic circulator to determine feasibility and perform critical experiments to verify the simulation results of selected component designs.

PHASE II: Phase II will design, model, fabricate and test optical circulator and isolators for application in photonic integrated circuits on a platform such as standard III-V, silicon or silica, that can include representative PIC component functionality having passive and active components. It is anticipated that Phase II should be an iterative approach comprised of two fabrication cycles to allow learning from the first cycle to be applied to optimization of the second cycle.

PHASE III: This work benefits large-scale integration of optical components needed to increase the functionality of DoD sensor systems or commercial high-speed optical networks. Phase III will transition this nonreciprocal component technology into selected PIC platforms used in DoD and/or commercial systems.

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KEYWORDS: integrated photonic circuits, optical isolator, optical circulator, RF photonics

AF151-152 TITLE: Compact, High Stability Master Oscillators for Airborne Coherent Laser Radar

TECHNOLOGY AREAS: Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: The goal is the development and demonstration of a compact, high stability, laser master oscillator for long-range coherent ladar.

DESCRIPTION: The overall objective is the development and demonstration of a compact, high stability, master oscillator for long range coherent ladar operations. Current Pound-Drever-Hall (PDH) techniques rely on relatively large, vacuum-isolated optical reference cavities for frequency stabilization. These reference cavities and their associated vibration and acoustic isolation systems currently range in size from 0.5 to 1.5 cubic feet. Although effective, these cavities are difficult to package and stabilize in highly dynamic flight environments. Methods to miniaturize master oscillator configurations will be investigated with a goal to achieve an "integrated circuit-scale” system. These methods may include novel approaches to miniaturize current PDH techniques as well as entirely new stabilization approaches that can provide the required stabilization performance and yield size, weight, and power (SWAP) reductions. This technology could be applied to multiple coherent ladar systems including synthetic aperture imaging, remote vibrometry, holographic imaging as well as radar, navigation, and timing. The listed coherent ladar capabilities have broad interest and use within the Air Force for combat identification applications; intelligence, surveillance, and reconnaissance needs; and targeting applications in air-to-air and air-to-ground scenarios.

To further spell out the requirements for this master oscillator, preferred methods will be applicable across wavelengths ranging from 1.5 microns to 2 microns; however, point designs at 2.0 microns, which has the highest priority, or 1.5 microns are acceptable. The threshold requirement for maintaining wavelength stability is +/- 50 MHz of the nominal operating wavelength. The master oscillator’s line width has a threshold requirement of 100 Hz and an objective of 10 Hz. The desired output power of the master oscillator is 20 mW. To provide some scope to the afore mentioned "highly dynamic flight environment", a desired operating environment (in terms of operating temperatures, motion, and vibration) would be a pod-based system. The flight envelope for a pod would include temperatures ranging from -20 to 50 degrees C; however, the pod internal environment is controlled to operate in a much tighter temperature range (e.g., 20 to 35 degrees C). Pods can operate over Mach 1 and experience up to 9g. When considering SWAP, proposed approaches will need to consider the kinds of constraints inherent to pod-based systems. To provide a point of comparison, LRU components for pod-based systems have sizes and weights that are on the order of 0.5 cubic feet and 20 pounds, respectively. Relative to these values, a significant reduction in SWAP is desired such that 0.1 cubic feet would be a threshold size for a complete system, including any vibration and acoustic isolation systems should the proposed approaches require them.

PHASE I: Develop concept designs and approach for compact, motion and vibration insensitive, master oscillator for coherent ladar. Appropriate initial laboratory demonstrations. No government-furnished equipment, data, and/or facilities are required for Phase I.

PHASE II: Develop detailed designs for compact, motion and vibration insensitive, master oscillator for coherent ladar. Develop breadboard prototype demonstrating key components and features.

PHASE III: Develop prototype designs for compact, motion and vibration insensitive, master oscillator for coherent ladar. Develop full prototype with demonstrations in a coherent ladar system in flight environment.

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KEYWORDS: master oscillator, laser, MOPA, stabilization, cavity reference, coherent detection, wavelength stabilized, frequency stabilized, ladar, vibrometry

AF151-154 TITLE: Influence of Long-range Ionospheric and Atmospheric Effects on Surveillance and Communication Systems

TECHNOLOGY AREAS: Battlespace

OBJECTIVE: Develop new analytical and computational algorithms for surveillance and communication systems with arbitrarily non-Kolmogorov type long spatial correlation properties, with combined effect of coherent and random ionospheric and atmospheric effects.

DESCRIPTION: In conventional approaches for assessment of ionospheric and atmospheric irregularities on radio frequency (RF) and optical system performance [1,2], it is assumed that 2D phase screens are statistically independent (delta-correlated) along the ray propagation direction. However, because of the assumption of statistical independence, this commonly used model cannot be applied for analysis of long-range propagation effects associated with large-scale coherent ionospheric and atmospheric structures with long correlation lengths. For the same reason, the conventional thin 2D phase screen approach does not permit analysis of RF and optical systems whose performance depends on the spatial correlation properties of ray path difference (piston phase) along the propagation path [3]. Among these systems for example are Next Generation Over The Horizon (NGOTH) radars and coherent imaging ladars. With an anticipated long operational range there is a growing need in novel physics based analytical and numerical techniques specifically designed to address challenges of long-range communications through the media with developed large scale coherent structures [4]. Proposed research effort should initiate the development of new 3D ionospheric and atmospheric propagation models with incorporated physics based models of coherent and random field density irregularities with at least one and up to two orders of magnitude potential performance improvement in resolution. Applicants should develop ionospheric and atmospheric physics based models for generation of 3D coherent and random large scale density irregularities with long-range spatial correlation properties. Performance parameters for such models should be able to cover the wide range of spatial scales from several kilometers to several centimeters. These new capabilities should enable high-accuracy analysis of long-range ionospheric and atmospheric effects on RF and optical systems with dramatic increase from at least one to up to two orders of magnitude in spatial and temporary resolution.

PHASE I: Develop physics-based models for generation of 3D coherent and random density irregularities with long range spatial correlation properties. Develop and optimize a 3D computer code based on new physics based models. Apply parallelization technique to increase performance.

PHASE II: Develop a propagation model with incorporated long range correlation properties of density irregularities for RF and optical applications, such as NGOTH radars, coherent imaging ladars and high-energy laser beam projection systems. Develop a numerical toolbox for evaluation of long-range military systems including active and passive imaging, NGOTH radars, adaptive optics, directed energy, laser communications, and laser designation. Compare the results with existing published experimental data.

PHASE III: Working with Air Force Research Laboratory scientists and engineers, integrate the developed software into the AFRL super-computer center and assist in transitioning to military and civilian applications.

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KEYWORDS: turbulence, wave propagation, space, ionosphere, atmosphere, long range correlation length, NGOTHR, coherent imaging ladar, adaptive optics, directed energy, laser communications

AF151-155 TITLE: Diffractive Optical Elements for Efficient Laser Cavities

TECHNOLOGY AREAS: Electronics

OBJECTIVE: Develop innovative approach based on high efficiency diffractive optical elements to replace currently used external bulk laser optics and to improve the stability of vertical external cavity laser systems as well as other solid state laser systems.

DESCRIPTION: The Vertical External Cavity Surface Emitting Laser (VECSEL) system has been used to directly generate visible through midway infrared spectrum, and have achieved over 100 W from a single emitter. These sources are suitable for many DoD applications such as infrared countermeasures (IRCM) and active laser sensing, specifically for airborne systems, due to size, weight, and power (SWAP) considerations. However, the VECSEL platform is less robust compared with most semiconductor lasers due to alignment-sensitive curved external optics. Replacing the external optics with diffractive optical elements (DOE) that may be bonded directly to the semiconductor will increase the robustness of the system, as well as stabilize the wavelength. The DOE approach may potentially be used with any other types of the lasers, not necessarily VECSELs. To date, however, efficient structures have typically utilized flat (non-curved) interferograms. Currently there are technologies available that may allow holographic recording of volume DOE structures in bulk optical materials, for example, DOE in photo-thermo-refractive glass (PTRG), or another example, 3-D surface etched gratings.

The goal of this research is to develop innovative DOE structures with low optical loss (less than 1 percent), high reflectivity (more than 96%), operating at high optical powers (100 W or more) at the wavelength around 1000 nm (design wavelength is TBD), transparent to the pump wavelength at around 808 nm, and suitable to replace concave mirrors used as an external laser cavity. Typical concave mirrors used in systems under development have radii of curvature 200-600 mm located at approximately 100-300 mm from the source.

There will be no need for government materials, equipment, data, or facilities in the initial phase of this research.

PHASE I: Develop innovative concept and perform a feasibility study of an optical system based on DOE that are suitable to replace bulky optical cavity mirrors used with VECSELs or any other types of solid sate lasers. It must be demonstrated that the new approach will significantly reduce the SWAP, while improving the stability and efficiency of the laser systems.

PHASE II: Based on the results of Phase I, develop a prototype DOE system to demonstrate in VECSEL cavities. Propose the design for operation at longer wavelengths (e.g., 3-5 microns). Coordinate with transition-metal solid-state laser community for applicability with tactical laser sources.

PHASE III: Coordinate with VECSEL manufacturer to integrate DOE VECSELs for DoD needs.

REFERENCES:
1. B. Heinen, T. L. Wang, M. Sparenberg, A. Weber, B. Kunert, J. Hader, S. W. Koch, J. V. Moloney, M. Koch and W. Stolz, “106 W continuous wave output power from a vertical-external-cavity surface-emitting laser (VECSEL),” IET Electronics Letters, 48(9), pp. 516, 2012.

2. T. Chung, A. Rapaport, V. Smirnov, L. Glebov, M. Richardson, and M. Bass, "Solid-state laser spectral narrowing using a volumetric photothermal refractive Bragg grating cavity mirror," Opt. Lett, 31(2), pp 229, 2006.

KEYWORDS: semiconductor-laser, VECSEL, vertical-cavity, infrared-countermeasures

AF151-156 TITLE: Overhead Persistent Infrared Tracking

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: The objective is to develop a suite of tracking solutions with an open architecture design applied to overhead persistent infrared (OPIR) data that is capable of tracking a wide range of target types.

DESCRIPTION: A variety of remote OPIR systems provide data to analysts tasked to extract activities of interest within the sensor data. Automated target detection and tracking are required to assist these analysts in understanding objects of interest captured with the OPIR systems. Objects of interest can vary in size and type to include a wide range of trajectories and signatures. A single tracking solution has been shown to be unsuccessful for all the analysts needs, leading to the requirement for a suite of novel trackers that can be applied to this data. Furthermore, these trackers must reside in a software architecture with the flexibility to incorporate other component level solutions (e.g., alternative detection methods or target specific feature-based trackers). Specific challenges include low Signal to Noise Ratio (SNR) and subpixel targets; large variations in sensing ground sample distance (GSD), sensor frame rate, target dynamics and signatures; needs for both multi-target and high-valued target solutions; and scalable solutions for very large image sizes. It is essential that experience with these challenges can be demonstrated or readily achieved.

The flexible software architecture must be capable of integrating with the Air Force Research Laboratory (AFRL) Government Algorithms for Tracking Exploitation Research (GATER) system. The GATER software and associated documentation will be provided as Government Furnished Data (GFD).

Synthetic or surrogate data will be provided as GFD for development and demonstration of the tracking capability. A baseline performance dataset will also be provided as GFD that utilizes the existing GATER trackers developed at AFRL. This baseline will be used by contractors to demonstrate the performance improvements by the methods developed under this effort. Performance evaluation of the tracking suite will be conducted using standard tracking metrics based on guidance obtained from the COMPASE Tracker Evaluation Software Suite (CTESS) which will also be provided as GFD.

PHASE I: Develop, demonstrate and deliver the tracking suite utilizing GFD. Apply tracking metrics when possible to establish baseline performance and/or demonstrate improvements resulting from algorithm developments. Deliver source code capable of being integrated with the GATER system. Deliver technical reports.

PHASE II: Demonstrate tracking suite performance utilizing GFD. Develop enhancements as needed to address performance issues from Phase I or those identified when processing the data in Phase II. Support integration of the tracking suite with the GATER system. Deliver updates to the software (source code) and technical reports.

PHASE III: Refine and harden the tracking software based on application to operational needs. Apply this technology to other IR data that would benefit from novel IR tracking methods. This will increase the commercialization potential and applicability outside government facilities.

REFERENCES:
1. Government Algorithms for Tracking Exploitation Research (GATER) Users Manual. Available from AFRL Technical Point of Contact (TPOC).

2. Government Algorithms for Tracking Exploitation Research (GATER) Interface Document. Available from TPOC.

3. COMPASE Tracker Evaluation Software Suite (CTESS) - Software Guide. Available from TPOC.

4. Samuel Blackman, Robert Popoli, Design and Analysis of Modern Tracking Systems, Artech House Radar Library, 1999.

KEYWORDS: target tracking, overhead persistent infrared

AF151-158 TITLE: Very Large Multi-Modal NDI

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: The objective is to move away from non-destructive inspection (NDI) hand-held operations to very large surface areas of aircraft structures that will reduce man hours and depot cycle times.

DESCRIPTION: As the age of our legacy fleets increase, there is an increasing requirement to scan very large areas of the outer mold line. Traditional inspection equipment were primarily designed as hand held operations for specific locations on the structure. This equipment was adapted for semi-automated operations and manipulation by computers and x-y scanners. Research should include but not limited to the use of array probes, both ultrasonic and eddy current, to increase the area that can be scanned at one time, increased scan speed, improve data collection rates, improve data fusion, and provide automatic defect recognition/reporting. This program will also investigate using multiple inspection modes simultaneously, (i.e., ultrasonic/eddy current, high frequency/low frequency). For example, the KC-135 has an inspection requirement on the crown skin for both a high frequency and a low frequency eddy current inspection of the spot welds. This currently requires two set ups and two separate scans. If high frequency and low frequency eddy current could be combined, this would result in an automatic 50 percent reduction in manhours, and the use of arrays will be faster than manual, further reducing the manhours required.

PHASE I: Research and develop concept of the core innovative technologies approach and report complete description in final Phase I report on how the technical approach will be applied to satisfying the Topic requirement. Provide a Phase II methodology development plan if selected for Phase II contract.

PHASE II: Continue research and development of technology for a prototype demonstration in an Air Force Sustainment Center (AFSC) complex facility and demonstrate the commercial viability of the approach. Develop transition plan for an enterprise wide implementation of the technology across AFSC complexes.

PHASE III: Dual application for the military and commercial industry that includes DoD maintenance depots and commercial aviation and automotive industry.

REFERENCES:

1. Technical Order 1C-135-36, para 8.4.2, 8.4.3 and 8.4.13.

2. Technical Order158 1B-52H-36, Fig 7-2.1.30.

KEYWORDS: large area NDI, multi modal, NDI, array probes, ultrasonic scan, eddy current

AF151-159 TITLE: <u>Multi-Layer Deep Structure NDI</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To provide a capability to perform non-destructive inspection (NDI) thru multipliable layers of aircraft structures to detect damage with high confidence and reduce cycle times performing inspections.

DESCRIPTION: Maintenance of the U.S. Air Force's legacy aircraft fleets entails numerous critical tasks for NDI of macro-scale flaws in structural components, especially various types of hidden corrosion, stress-corrosion cracks, and fatigue cracks. This structural damage often occurs in deep, complex, multi-layered structures, buried underneath other aircraft components, and is generally very difficult to access. However, regular inspections are required for any safety critical damage; as a result, aircraft mechanics may spend several days removing – and afterwards securing and reassembling - structures to gain access to an area for a nondestructive inspection that might only take less than 30 minutes to perform. This access time is a serious impact to the flow days of programmed depot maintenance and increases the risk of maintenance induced damage. Thus, a strong demand for new NDI technologies exists to perform reliably inspections of deep, hidden crack or corrosion flaws in a depot aircraft maintenance environment.

Air Force maintenance, including NDI procedures, are being enhanced to meet the requirements laid out by the Aircraft Structural Integrity Program (ASIP) based on a damage tolerance approach. As a result, the requirements for research, development and application of new NDI initiatives has to significantly improve overall NDI capabilities, not only reduce the burden of time and cost intensive inspection, but also to ensure the reliability of the inspection results and, to increase the safety of continuous operation for the aging Air Force aircraft fleets. As stated, improving flaw detection beyond the first layer in multi-layered, complex, and difficult to access structures is a highly critical inspection need. Approaching this problem, however, requires a comprehensive understanding of its daunting complexity. To illustrate this complexity, a list of factors affecting NDI for cracks in a two-layered strcutre was generated [1]. These factors were categorized as being originated by the 1) employed NDI method, for instance, the coupling conditions between a contact ultrasonic transducer and the test piece surface, 2) part geometry, material and condition, including complexity of layered-structure, presence of sealant material between layers, previous repair situation, etc., and 3) flaw characteristics, including flaw number, type, size, location, etc. Understanding of the factors and their respective separate and synergetic influences on both the potential to implement a new approach and the resulting measurement data is essential.

Within the scope of this effort, new and innovative NDI technology will be developed demonstrating reliability and feasibility to inspect deep flaws in complex, multi-layered structures. No limitations regarding the NDI technology are given; however, a successful capability demonstration will require a thorough inclusion of all structural boundary conditions and specific inspection conditions. The emphasis is on deep flaw detection development in metallic structures, thus, candidate NDI solutions will concentrate on corrosion and/or crack detection applications.

PHASE I: Research and develop innovative technology for deep structure detection. In Phase I's Final Technical Report provide the technical approach that can describe the NDI concept approach that, if awarded for Phase II, could be developed for a pilot demonstration. Develop Phase II approach on investigating full aircraft structures.

PHASE II: Continue research based on Phase I demonstration and develop the feasibility of NDI approach on aircraft structures. Perform a reliability assessment first in a relevant environment and then in an operational environment in accordance with MIL-HDBK-1823. Develop transitioning and implementation Plan.

PHASE III: Transition and implement inspection into Air Force, DoD and commercial maintenance procedures.

REFERENCES:
1. E. Lindgren, C. Buynak, “Materials State Awareness for Structures Needs and Challenges,” presented at 12th International Symposium on Nondestructive Characterization of Materials, 2011, Blacksburg, VA, USA.

2. FAA DOT/FAA/CT-94/11 Emerging NDI for Aging Aircraft
http://www.faa.gov/about/initiatives/maintenance_hf/library/documents/media/human_factors_maintenance/ct94-11.pdf.

KEYWORDS: NDI, non-destructive inspection, deep structure inspection, multiple layers

AF151-160 TITLE: Alternative Materials to Cu-Be for Landing Gear Bushing/Bearing Applications

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Evaluate at least two candidate bushing alloys as potential replacements for Copper-Beryllium (CuBe).

DESCRIPTION: CuBe alloy C17200 is of composition Cu-2wt%Be -0.4wt% (Co+Ni+Fe). Specification AMS 4534 (Cond TH04) covers rod and bar products which are solution treated, cold worked, and precipitation heat treated, which is specified for CuBe bushings of highest strength and wear resistance.

CuBe alloy is the highly wear resistant, high strength bushing material utilized frequently in landing gear applications. For Air Force landing-gear systems, CuBe in the highest strength condition is the choice when excessive wear from field service underscores a need for greater wear resistance than standard Al-Bronze or Ni-Al-Bronze bushings. However, because of the toxic constituent Be, the eventual removal of CuBe bushings from DoD weapon systems appears likely. A potential toxic health hazard exists from wear debris generated in-service, which then results in uncontrolled exposure to maintenance personnel. Beryllium is a Category I carcinogen, and fine particulate inhalation of Be can result in beryliosis.

This effort is to research and qualify substitutes for CuBe material in high load landing gear applications, primarily on F-16 (about 3" outside diameter max) but also on C-5 (about 5" diameter max). Mechanical property objectives include ultimate tensile strength within 12 percent of CuBe and elongation of under 3 percent; desired friction wear is no more than .9 percent diametral wear depth (threshold) with an objective goal of .5 percent diametral wear. Of particular concern is high contact stresses and loss of lubrication on joints, which may often include chromium plate and High Velocity Oxygen Fuel coatings. Therefore, oscillatory endurance wear testing as well as dithering-type movement should be examined.

It is expected that materials proven through this effort will also be suited to other commercial and military landing gear applications.

PHASE I: Survey current progress of similar efforts on other military systems and perform mechanical testing to verify the above properties. Materials should be tested (with CuBe for a baseline) in landing gear representative pin-bushing combinations (e.g., 300M material chrome-plated coated pins; also note that landing gear joints are typically designed with a .001”-.002” diametric clearance).

PHASE II: Perform extended wear testing on candidates identified in Phase I to demonstrate wear performance characteristics comparable to CuBe and to validate for implementation. Demonstration of material scale-up to sections up to 5" diameter. Factors sufficient testing will be done to enable statistical comparison of wear values. Variations in contact stress, oscillatory movement distance and speed should be considered.

PHASE III: Implementation of successful Phase II candidates including technical data and processes/procedures for depot and intermediate maintenance. Prepare field service evaluation articles.

REFERENCES:
1. Technical Order 4S-1-182.

2. AF Research Laboratory, “Final Report for the Metal Affordability Initiatives (MAI) Alternatives to CuBe (ACUBE) Program.”

KEYWORDS: Copper-Beryllium, Beryllium elimination, Beryliosis, Carcinogen

AF151-161 TITLE: Innovative Technologies for Automated Capacity Assessment and Planning for Manufacturing

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To develop a methodology for real-time capability and capacity assessment of manufacturing machines, planning, and analysis in critical DoD production and repair facilities using real time manufacturing process and operational performance data.

DESCRIPTION: Currently, available methods/processes/systems to accurately identify or define manufacturing production and repair process capabilities do not exist. Air Force Materiel Command is presently engaged in a significant Depot Level Repair in-sourcing activity which requires accurate identification and definition of Maintenance capabilities. Not having a readily available and real time method that documents specific capabilities draws heavily upon DoD’s personnel resources to determine on case by case basis. A readily available and real time method/process/system would reduce the strain on personnel and allow for a quicker War Fighter response to emerging aircraft issues. It is critical that DoD’s maintenance have real time access that reflects current capacity/utilization percentages to ensure surge capacity limits are protected, business development opportunities are identified quickly, and effective utilization of DoD’s own capabilities are achieved. A readily available and real time capability and capacity method/process/system needs to be performed using real-time data sources and KPIs (Key Performance Indicators). This project would increase workload effectiveness (optimization of existing capabilities and bidding on new workloads), show potential technology gaps, and ensure maximum usage of funds for improvement. Although AFMC is developing a common maintenance, repair and overhaul system (MROi) to better assess production line performance, that tool will fall short in providing analysis of where the depot enterprise's capability and capacity can be best utilized. MROi will not provide the information needed for depot maintenance decision makers to decide where to activate or realign workload so that each production line is operating at its most efficient level.

PHASE I: Research and architect the capacity assessment methodology, identifying the core technologies that will be applied in satisfying the requirements. Develop a Phase II methodology development plan and roadmap for implementing solutions in production and repair manufacturing facilities.

PHASE II: Implement the Phase II methodology development plan, and develop a prototype demonstration of the selected approach in DoD's organic manufacturing facilities and demonstrate the commercial viability of the approach. Deliver the prototype software system with adequate documentation such that it can be applied across other DoD facilities.

PHASE III: Military application: DoD suppliers, production facilities, depots, bases, and arsenals. Commercial Application: Commercial aviation and automotive manufacturers.

REFERENCES:

1. Eckert, M., Bry, u.F., 2009, "Complex Event Processing (CEP)," Inf.-Spektrum, 32:2, pp. 163-167.

2. Morrison, C.J., 1997, "Assessing the Productivity of Information Technology Equipment in the U.S. Manufacturing Industries," The Review of Economics and Statistics, 79/3: 471-481.

3. Ray, S., 2005, "Manufacturing Interoperability," J. of Int. Manf, 17:6, pp 681-688.

4. Vijayaraghavan, A., Sobel, W., Fox, A., Warndorf, P., and Dornfeld, D. A., 2008, "Improving Machine Tool Interoperability using Standardized Interface Protocols: MTConnectTM," Proc. of International Symposium on Flexible Automation.

KEYWORDS: capacity assessment, capacity planning, capacity analysis, OEE, KPI, manufacturing, machining, process technologies, surge readiness, interoperability standards, open protocols

AF151-162 TITLE: Non-Destructive Inspection Data Capture

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop advanced techniques to streamline non-destructive inspection (NDI) operations to improve accuracy, minimize data translation errors, and eliminate redundant data entry thereby decreasing flow time while maintaining a high quality process.

DESCRIPTION: Due to the age and high usage levels of much of the Air Force fleet, NDI is more critical than ever to ensuring the health and safety of the aircraft. NDI uses many different techniques such as eddy current, ultrasonic, etc to identify difficult to detect and/or unforeseen issues associated with the aircraft. While new and ever more sophisticated techniques to identify defects are available, the processes to document the defects and share the findings with engineering and other stakeholders has changed very little over the years. The current process is a manual, time consuming, paper-based process, relying heavily on forms to document specific findings. It requires the artisan to be highly knowledgeable in not only the specific NDI technique, but also the specific aircraft and documentation for the specific aircraft. While portions of the data are entered into computer systems, other pieces of data are only available locally. Most of the data captured is non-standard, and requires extensive data mining before trend analysis can be conducted across multiple aircraft.

This project would analyze the processes, and research methods for types of data being captured to identify opportunities to streamline the procedures, present the data more efficiently to all stakeholders, and standardize the results for future analysis. Air Force NDI focal points will work with Air Force Sustainment Center's NDI Program Manager in providing examples of data collection requirements and form examples. The new concepts should address both NDI needs as well as engineering requirements without overburdening personnel with data collection and analysis tasks. It must also consider the experience and time constraints of the NDI artisan, and simplify the process where at all possible. The new concepts must be flexible enough to address multiple aircraft types. While much research has been conducted on NDI analysis techniques, the focus has been on equipment and operations. There are many gaps in the research associated with data capture along with limited research data available on detailed fleet analysis and maintenance operations. Any approaches to solving the issues must take into account the physical constraints, security protocols, and personnel restriction/limitations. The resulting concepts/processes/training must be demonstrated with the context of the depot repair environment and must follow the strategic, operational, and tactical framework of DoD depot repair processes.

PHASE I: Research best NDI data capture concepts to meet needs and resolve the constraints and/or potential quality issues associated with NDI. Based on the results of the research performed, develop a concept demonstration for assessing the program's feasibility for Phase II.

PHASE II: Develop a real world demonstration of the concepts/processes/training to be assessed by managers involved in the NDI processes. The demonstration should include the integration of the concepts/processes/training in at least two different areas. The program shall also provide a plan to transition the technology to commercial development and deployment.

PHASE III: Military: Applicable to aircraft, engines, and subassemblies. Commercial: It could have a significant impact on material quality, accuracy, efficiencies, and throughput. The processes and/or technology selected will improve quality, reduce costs, and increase throughput.

REFERENCES:
1. Thomas H Davenport, International Institute for Analysis, "Enterprise Analytics: Optimize Performance, Process, and Decisions Through Big Data," FT Press, c2012.

2. Oral Buyukozturk, Mehmet Ali Tasdemir, Oguz Gunes, Yilmaz Akkaya, "Nondestructive Testing of Materials and Structures," Springer, c2011.

3. Mohammad Modarres, "Risk Analysis in Engineering: Techniques, Tools, and Trends", CRC Press, c2006.

KEYWORDS: non-destructive inspection, data capture, data analysis, NDI

AF151-163 TITLE: Landing Gear Bushing Installation

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Qualify products, processes, and /or technology that can establish a best practice for bushing installation into high strength steel an aluminum landing gear parts.

DESCRIPTION: Bushing wear within landing gear components is a significant maintenance driver for all Air Force landing gear systems. The maintenance includes identification, inspection, bushing replacement to include custom fitting and alignment boring/reaming and component substrate processing for corrosion and oversizing. The scope is to evaluate the entire process.

Abnormal wear can be attributed to improper bushing installation. The improper installation can be attributed to both process and methods or to using improper or inadequate material. In addition to the issues involving wear, there are complications such as bushing movement. The movement can be rotational, or axial migration, or a combination of both. Factors such as adhesion and press fit are to be evaluated.

Along with the bushing problems there are significant impacts due to corrosion between the bushing and the mating surfaces. This corrosion is a driver for excessive rework and condemnations during overhaul or repair.

Implementation of validated/standardized bushing installation procedures will have a significant positive influence on the performance and life cycle cost of every weapon system. The approved process will provide standardization of landing gear bushing installation across Air Force field units, depots, and manufactures. The emphasis would be a proper installation process to become a Air Force standard as well as evaluate corrosion inhibitors to be used in the process. Expected benefits will be a decrease in bushing bore oversize repairs. Reduction in condemnations due to oversize bushing bores. Reducing maintenance workload due to bushing issues such as migration or wear due to improper installation.

The investigation will identify the proper equipment, materials and processing steps for installation and removal of bushing from 1/4” to 6” diameter. Standardized bushing installation or commercial off-the-shelf tooling, materials and processes shall be investigated, for optimization of bushing installations for both depot and field units.

Post installation machining or finishing such as line bore or reaming shall also be evaluated. This process currently uses both hand held honing bars and stationary honing stations.

Currently there are a number of approved installation methods: Fillet sealants to create moisture barriers, corrosion inhibitors applied prior to install, paint primer installed wet or dry, and polysulfide used during installation. In the selection of material; factors such as aging, durability and effectiveness shall be evaluated.

PHASE I: Develop a solution that meets above requirements and conduct preliminary business case analysis (BCA) to determine implementation costs, including a return-on-investment (ROI) calculation that compares anticipated savings to expected costs. Mishap avoidance shall not be included in cost calculations. Proof-of-concept prototype(s) shall be developed to demonstrate conformance to the requirements.

PHASE II: Proof of concept prototype(s) shall be refined to a flight-ready article and shall undergo testing to validate all requirements. This process may require multiple iterations before a final design is selected. Refine BCA/ROI based on the final design.

PHASE III: Will be implemented by Air Force only if the BCA/ROI is adequately justified and the final design is acceptable. A successful product may be adopted by all DoD and commercial aviation.

REFERENCES:
1. Technical Order 4S-1-182, General Strut.

2. Technical Order 1-1-691, Cleaning and corrosion Prevention.

3. Technical Order 1-1-8, Aerospace Coatings.

KEYWORDS: aircraft, air, craft, bushing, installation, pressure, tolerance, machining, reaming, boring, visual, tool, inspection

AF151-166 TITLE: <u>Thermal Spray Dashboard/Knowledge Management System</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Improve thermal spray application process through reduction in variability and increase in overall improvement in process efficiency.

DESCRIPTION: The thermal spray dashboard/knowledge management system requirement is to pull collected information from lab reports/evaluations, PlumeOpt, thermal spray system run data and engineering copulated data to monitor the thermal spray process as well as help with troubleshooting, quality measurements, and process improvement procedures. The dashboard will help streamline and assist process engineering and production personnel with ensuring an efficient, consistent process is achieved with the final product being a quality coating applied to various engine components. The dashboard/knowledge will also streamline research and development and qualification projects with providing accurate data/procedures. All of these factors' long-term effects would be cost savings in lab testing, qualification procedures troubleshooting and production running. Once enough data is collected and consistently analyzed preventative procedures can be put in place to ensure minimum amount of production down time and rework of under quality sprayed parts.

Long-term factors would be a reduction of one for one lab testing of thermal sprayed coupons and increased production output of various thermal coated engine components. After a given amount of time the collected data will help with preventative maintenance of thermal spray equipment and reduce down time for repair. Streamlining the thermal spray process will make it easier for workload to be moved from booth to booth with minimum amount of qualification time and minimum variance in quality output.

PHASE I: Research and develop a methodology that demonstrates the results in a data system of the various thermal spray process data and integrate the various information in such a way that it can be interpreted and utilized to streamline and troubleshoot the thermal spray process. This concept approach will also provide information to create preventative measurement procedures for the process.

PHASE II: Expand on Phase I methodology concept and develop the capability resulting in pilot working environment to validate the design and capability. Operational testing of pilot during Phase II will determine effectiveness and what actions will be needed for a production system.

PHASE III: Resulting capability will be implemented by Air Force's Air Logistics Complexes, as well as being available to commercial depots that utilize thermal spray production or for repair applications.

REFERENCES:
1. Process Order 85-11.

2. Technical Order 2-1-1-11.

KEYWORDS: thermal spray, dashboard, monitoring, process control

AF151-167 TITLE: Prognostic Scheduling

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop prognostic capabilities for autonomous maintenance re-planning.

DESCRIPTION: The Air Force's Air Logistics Complexes (ALC) are tasked with the responsibility of maintaining the Air Force’s fleet. Currently, master planners, using a variety of tools, develop the maintenance plans based on the incoming air platform, work requirements, priority, and availability of resources to develop the maintenance schedule [1]. The master scheduler relies on experience and foreknowledge to develop the plan. However, these static plans can be interrupted by unscheduled work and delays. Furthermore, with the large number of aircraft coming through the ALC, maintaining knowledge on the individual aircraft and properly applying that knowledge is extremely time consuming and difficult. This method does not include any prognostic capability into the scheduling that may assist in reducing the amount of re-planning necessary. Currently, there is no means to assist the scheduler in dynamically re-planning that also includes the aircraft detail.

The current method relies heavily on human-in-the-loop to perform scheduling so that when an unplanned event occurs it becomes a labor intensive operation to analyze and re-plan the schedule leading to delays. A new paradigm is needed to move the current re-planning effort from a static level process to a dynamic level process that incorporates aircraft prognostics [2]. The new human-on-the-loop process becomes executive monitoring to verify the updated schedules are easible and can be adjusted as needed.

The new paradigm will require the incorporation of powerful mathematical and algorithmic tools. Data mining and fusion are needed to identify the critical information needed to make intelligent decisions. Information reasoning will be needed to predict future bottlenecks and dynamically react to them. The master scheduler will benefit from being able to maximize depot throughput while maintaining work requirements in a dynamic environment.

PHASE I: Using COTS/GOTS software, the Phase I research will develop the initial tools and concepts to achieve prognostic scheduling. Phase I will focus on defining the concept and developing a concept demonstration of the algorithm.

PHASE II: In Phase II, the performer will develop the algorithms into a prototype. The contractor will test the algorithms against historical data. Transitioning of the final package to Air Force operations must be considered.

PHASE III: This phase will result in a fieldable package that can be installed in ALCs and other Air Force facilities to augment current planning/scheduling software and improve the efficiency of maintenance and related operations.

REFERENCES:
1. Cooley, H., "C-130 Programmed Depot Maintenance Processes," www.dtic.mil/get-tr-doc/pdf?AD=ADA546160.

2. Wikipedia, "Prognostics," http://en.wikipedia.org/wiki/Prognostics.

KEYWORDS: prognostics, dynamic re-planning, human-on-the-loop, Information reasoning, data mining, data, fusion

AF151-168 TITLE: Strip Solutions to Optimize the Stripping of Plating and Thermal Spray Coatings

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Research, develop, and validate stripping solutions used at Tinker AFB, Okla., to establish operating limits of solutions and stripping procedures that result in the best stripping rate.

DESCRIPTION: Stripping solutions are used at Tinker AFB to remove coatings such as nickel plating, chrome plating, silver plating, and numerous types of thermal spray coatings. Research of these solutions is required to further optimize the stripping rate of these solutions to decrease flow days and increase life of part through minimizing part time in solution. Contaminants in stripping solutions are inevitable throughout the use of the solution, but they can greatly affect the stripping efficiency of the stripping solutions over time. More information is needed on these saturation limits to determine when it is cost effective to continue running and when it is cost effective to replace the solution.

Research effort needs to be performed to provide innovative solution to address the above that result in reduced time to remove coating material in strip processes while optimizing all inputs that contribute to the best process. Solution should address any appropriate environmental reductions and insure no health concerns will be an issue.

PHASE I: Research and develop concept of the innovative technical approach and report on how the approach will be applied to satisfy the Topic requirement. Final Phase I report should document concept and include a Phase II methodology development plan if selected for a Phase II contract.

PHASE II: Continue the research and development of technology concept presented during Phase I for a prototype demonstration in an AFSC Complex facility and demonstrate the commercial viability of the approach.

PHASE III: Dual application for both military and commercial aviation maintenance depots.

REFERENCES:
1. Process Order 86-005.

2. Technical Order 2-1-1-11.

KEYWORDS: strip plasma coatings, nickel plating, chrome plating, silver plating

AF151-169 TITLE: Visual Tire Pressure Indication

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Research and develop a method/device to visually verify tire pressure on aircraft wheels. The device shall be simple and low cost, integral to the valve stem and/or valve cap, and useable and customizable for multiple aircrafts requirements.

DESCRIPTION: Low tire pressure has been the cause of tire failures on both military and commercial aircraft. These failures have resulted in aircraft damage (low tire pressures may have resulted in the loss of a weapon system or life). Maintenance crews are tasked with frequently measuring tire pressures and servicing tires to maintain the required aviation tire pressures. These maintenance procedures add additional risk to the maintenance of aircraft. Tire failures can often be attributed to lapses in maintenance. Low tire pressure also reduces tire life which increases operational costs. A quick visual check of a tire pressure indicator prior to launching an aircraft would reduce the risk of possible damage and reduce cost of flying.

The Air Force is interested in developing a simple, reliable, cost effective device that will visually indicate the tire pressure. The indicator shall be visible and distinguishable from at least 10 feet for unaided eyes. The indicator shall constantly display the tire pressure. The device shall have at least two indication methods: proper inflation and incorrect inflation. The device indication methods shall be easily customized to match the required tire pressures for the given aircraft / sortie. Accuracy of the device shall match the accuracy currently required for manual tire pressure gauges. The device shall be highly reliable, but shall be fail safe in that it will not indicate proper inflation if the device has malfunctioned. Although it is expected that the device will be larger than the current valve stem and/or cap, the size of the device shall be such that it will not interfere with any other surface. The device shall not interfere with any other aircraft function. The device will allow tire servicing and traditional pressure checks using current Air Force tooling. The design shall be able to survive military aircraft usage environments including, but not limited to, factors such as: durability, shock resistance, vibration, heat, cold, ice, salt spray, water, air flow, debris, G-loading, etc. It shall not create a foreign object debris, or FOD, hazard. There shall be no risk of loss of air pressure due to the device. The device must be able to satisfy all applicable air worthiness requirements.

Past efforts have been made to simplify the manner at which tire pressures are measured. To date, no cost effective solutions have become available. The current valve stem assembly is approximately $10 dollars. To successfully accomplish a business case analysis (BCA), the device shall have a minimal increase in cost. The large quantity of aircraft wheels in the Air Force fleet will make any solution that is cost prohibitive nearly impossible to implement.

No Government equipment or facilities will be provided for this research and development effort. Applicable data, including technical orders and existing research, will be provided as requested.

PHASE I: Research solution(s) for the above requirements with a preliminary BCA. The BCA shall determine costs; with a return on investment (ROI) calculation that compares the anticipated savings to the expected costs. Mishap avoidance shall not be included in cost calculations. Design concepts shall be developed to demonstrate conformance to the requirements.

PHASE II: The design concepts shall be refined to create proof of concept prototype(s). The prototype(s) shall undergo testing to validate all requirements. The contractor shall coordinate with the government to select a robust test plan. Among the required tests are: durability, shock resistance, vibration, ice, salt spray, water, air flow, G-loading, pressure reading, fail safe, temperature, shock resistance, calibration, ease of use, readability, etc. Refine BCA/ROI based on the final design.

PHASE III: Phase III testing will proceed only if the BCA/ROI is adequately justified and final design is acceptable. The testing includes: flight testing multiple weapon systems, installation processes and maintenance requirements. A successful product may be adopted by all DoD and commercial aviation.

REFERENCES:
1. Technical Order 4W-1-61, General Wheel.

2. Technical Order 4A4-77-3, F-16 Main Landing Wheel.

3. Technical Order 4T-1-3, General Tire.

KEYWORDS: aircraft, tire, inflation, pressure, check, indication, valve, stem, cap, visual, tool, wheels, rims

AF151-173 TITLE: Advanced Experimental Design and Modeling and Simulation for Testing Large Format Sensor Arrays

TECHNOLOGY AREAS: Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop new test techniques for next-generation large format imaging, multi- and hyper-spectral, and wide field of view (WFOV) sensor systems with large-format focal plane arrays.

DESCRIPTION: New test techniques are needed to test next generation imaging, multi- and hyper-spectral, and wide-field-of-view (WFOV) sensor systems with large-format focal plane arrays using large-format projection systems. Infrared and visible sensor systems are increasing in complexity; this includes high-resolution focal plane arrays (FPA) with larger numbers of pixels, WFOV optical telescopes ranging from a fraction of a degree to tens of degrees FOV coverage, and broad spectral coverage with multispectral and hyperspectral applications. These developments are proceeding faster than ground-test facilities can be built or modified for accurate testing. Current full-coverage testing methodologies are limited to sensors with FPAs on the order of 256x256 pixels and cannot test FPAs with 1024x1024 to 2048x2048 pixels, or sensors that consist of multiple FPAs combined and packed to create a mosaic of arrays. Testing larger sensor FOVs drives the need for increasingly larger and more complex collimator projector optics to fill the sensor's FOV. New testing methodologies that combine optimal experimental design with modeling and simulation of facility and sensors will allow effective use of existing test facilities in these new and more stressful test regimes. New innovative test methodologies and related software tools are needed to test the more complex sensor systems. Phase I should demonstrate a testing methodology with a prototype experimental design to test sensors with infrared arrays of at least 4096x4096 pixels using existing capabilities comparable to the 7V Chamber and Space Systems Test Facility at the Arnold Engineering Development Complex (AEDC), Tenn., or test cells at the Utah State Space Dynamics Laboratory. Phase II should extend these capabilities to accommodate FOVs from one to 30 degrees for both visible and infrared spectral ranges without changing the hardware merging existing test capabilities with Modeling and Simultion of part of the article under test..

PHASE I: Develop and demonstrate an innovative testing methodology to test next generation sensors.

PHASE II: Demonstrate testing methodologies to extend these capabilities to FOVs varying between one and 30 degrees without changes to optical hardware and to include the visible and infrared spectral ranges.

PHASE III: Military: IR sensor developers, IR test equipment provider to DoD to provide more compact and efficient systems for customers such as the Air Force, MDA, DoD, NASA, and other agencies. Commercial: Earth Landsat and resource satellite and mapping sensor calibration, and astronomical survey systems.

REFERENCES:
1. Lowry, H.S., "Developing the Test and Evaluation Infrastructure at AEDC for Space Sensor Testing," AIAA-2008-1641 (T&E Days).

2. Preuss, Paul, “Building the Massive Simulation Sets Essential to Planck Results,” Lawrence Berkley National Lab, 14 Mar 2013.

3. “Raytheon Develops World"s Largest Infrared Light-Wave Detector,” 11 Aug 2009, ASD News.

KEYWORDS: sensor, large format focal plane, sensor array testing

AF151-174 TITLE: Background-Oriented Schlieren 3D (BOS-3D)

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Identify and develop analysis techniques and tools to measure and map the three-dimensional movement of a blast pressure wave after a warhead explosion.

DESCRIPTION: Warhead arena testing has been accomplished to characterize the fragmentation of Air Force warheads, but has made little progress in understanding the interaction of shock/pressure waves with surrounding structures, targets and secondary debris. There is a Department of Defense-wide requirement to understand the lethality and collateral damage effects for current weaponry, as well as those that are designed to minimize collateral damage. General requirements for a 3D shock wave tracking system are:
1. Integrate with existing and planned arena data collection techniques.
2. Determine a method to map a weapon blast pressure wave and time-sync its movement in order to correlate its movement with fragment position and velocity data (produced by a separate program).

PHASE I: Identify alternate methods for mapping and tracking a blast pressure wave in 3D space. Evaluate these methods sufficiently for alternative selection prior to Phase II.

PHASE II: Develop a software/hardware based prototype to implement shock-wave tracking technology in 3D space for eventual implementation on a DoD arena range. Evaluate this alternative based on its efficacy across a spectrum of expected weapons tests (<10lbs of explosive, 10-100 lbs of explosive, >100 lbs of explosive).

PHASE III: The tracking of in-air disturbances (shock waves, thermal conduction) is both applicable for military and commercial use (educational institutions, manufacturing and assessment of heat flow in housing). Airline manufacturers can use the technology to build better cabins that withstand explosions.

REFERENCES:
1. “Natural-background-oriented Schlieren imaging,” June 2009, Penn State University, Michael Hargather, Gary Settles.

2. “Demonstration of the applicability of a Background Oriented Schlieren (BOS) method,” Institut fur Stromungsmechanik, 1999, H. Richard, M. Raffel, M. Rein, J. Kompenhans, G.e.a. Meier.

3. “Density measurements using the Background Oriented Schlieren technique,” Experiments in Fluids, 2004, L. Venkatakrishnan, G.E.A. Meier.

KEYWORDS: pressure wave, shock wave, Schlieren, arena, weapon effects, collateral damage, lethality, munitions testing

AF151-175 TITLE: Gigapixel High-Speed Optical Sensor Tracking (GHOST)

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop photographic technology to enhance our ability to determine fragment physical characteristics in-flight.

DESCRIPTION: Warhead arena testing has been accomplished to characterize the fragmentation of Air Force warheads, but has done so using expensive and time-consuming technologies (usually involving firing into bundles and finding the fragments by hand). There is a Department of Defense-wide requirement to better characterize the size and shape of fragments from munitions, in order to determine the lethality and collateral damage effects for current high-explosive weaponry, as well as those that are designed to minimize collateral damage. General requirements for high resolution fragment photography:
1. integration with existing and planned arena data collection techniques;
2. determine how to integrate multiple cameras to produce gigapixel or near gigapixel images with integration times (shutter speeds) of 2-3 microseconds;

Commercial gigapixel technology is a new field with the first commercial camera already available. The ability to produce high speed gigapixel images requires the development of the technology discussed here.

PHASE I: Identify techniques for multi-scale gigapixel photography that will allow synchronized detectors to capture digital images of fragments moving at up to 9000 feet per second to determine fragment size and shape. The technique/prototype must be able to work in a traditional warhead arena test Evaluate these techniques for alternative selection prior to Phase II.

PHASE II: Develop a software/hardware based prototype to characterize fragment size and shape within a DoD arena test setup. Evaluate this alternative based on its efficacy across a spectrum of expected weapons tests (<10lbs of explosive, 10-100 lbs of explosive, >100 lbs of explosive).

PHASE III: The military and commercial application is useful in modern photographic arts and cinema and may have application in high-speed manufacturing and quality assurance processes.

REFERENCES:
1. "One-shot gigapixel camera offers a future beyond flat sensors," Digital Photography Review, Jun 2012, Richard Butler.

2. "About the qG Camera," aqueti.com, Aqueti, Inc.

KEYWORDS: fragment, arena, weapon effects, collateral damage, lethality, munitions testing

AF151-176 TITLE: Temperature/Heat Flux Imaging of an Aerodynamic Model in High-Temperature, Continuous-Flow Wind Tunnels

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop and demonstrate an innovative imaging method for surface temperature and/or heat flux of an aerodynamic model in a continuous flow wind tunnel for long test durations.

DESCRIPTION: Time resolved surface temperature and heat flux measurements of aerodynamic models are needed during continuous, high Mach number, wind tunnel testing. Currently, heat flux measurements are typically performed at discrete points using small-diameter Schmidt-Boelter heat flux gages that are difficult to install within a model and often damaged at prolonged exposure to high temperatures. Two test facilities at the Arnold Engineering Development Complex, Tenn., with this need are Tunnel B, with a stagnation temperature range from 416 to 750 K and a stagnation pressure range from 40 to 900 psi, and Tunnel C, with a stagnation temperature range from 933 to 1200 K and a stagnation pressure range from 200 to 2000 psi. Noncontact, optical-based techniques that provide continuous, "global" measurements over the entire model surface are needed to obtain comprehensive data and greatly improve testing efficiency. Optical methods could be used to measure heat flux directly or measurement of surface temperature, from which heat flux data could be determined using numerical modeling of the test model's internal heating. The optical methods could be based on characteristics of the model surface, such as its infrared emission or changes in emissivity (e.g., direct, multispectral, or hyperspectral thermal imaging). Methods requiring application of coatings to the test model, such as temperature sensitive paint, thermographic phosphors, or high emissivity paint, will be considered, but must easily applied and easily removed to avoid permanent alteration of the test model. Also, coatings must not substantially alter the aerodynamic characteristics of the model surface, such as surface roughness, and the model "mold lines." Vapor deposition and plasma spray methods for these coating applications will not be acceptable. A minimum temperature measurement resolution of 0.5 K is needed and a temperature rise of 20 K over 2 minutes is to be expected. A 1 x 1 mm spatial resolution is desired, but 5 x 5 mm will be minimally acceptable. Phase I should provide a preliminary optical-based system design describing the precision and accuracy along with a technical trade study for test facility implementation. Principal components of the design concept should be demonstrated for minimum spatial and temperature resolution. If coatings are to be used, thermal durability and sufficient high light yield should be demonstrated for high temperatures along with the application and removal of the coatings from a surrogate wind tunnel model made of stainless steel.

PHASE I: Demonstrate the accuracy and precision of a prototype optical system concept for spatial and temperature resolution.

PHASE II: Develop and demonstrate the prototype optical system in a government-furnished wind tunnel environment or similar operational environment.

PHASE III: Military: In-situ flight testing of hypersonic weapons systems. Commercial: High temperature manufacturing operations that require highly accurate, noncontact temperature and/or heat flux measurements and remote sensing application in commercial wind tunnels and other test facilities.

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1. Hawkins, W. R., Kidd, C. T., and Carter, J. S. A New Heat Transfer Capability for Application in Hypersonic Flow Using Multiple Schmidt-Boelter Gages. AIAA Paper 99-0945.

2. Kidd, C. T., and Adams, J. C, Jr. 2001. Fast-Response Heat-Flux Sensor for Measurement Commonality in Hypersonic Wind Tunnels. Journal of Spacecraft and Rockets. Vol. 38, pp. 719-729.

3. Liu, T, and Sullivan, J. P. 2005. Pressure and Temperature Sensitive Paints. Springer: Berlin.

4. Allison S. W., and Gillies, G. T. 1997. Remote thermometry with thermographic phosphors: Instrumentation and applications. Review of Scientific Instruments, Vol. 68, pp. 2615- 2650.

5 Hollerman, W. A., Guidry, R. F., Womack, F. N., Bergeron, N. P., Allison, S. W., Beshears, D. L. Cates, M. R., Godeke, S. M., Bencic, T. J., Mercer, C. R., and Eldridge, J. I. 2003. Use of Phosphor Coatings for High Temperature Aerospace Applications. AIAA Paper 2003-4585.

KEYWORDS: non-intrusive temperature, temperature sensitive paint, thermographic phosphors, thermal emission imaging, hyperspectral imaging, heat flux measurement

AF151-177 TITLE: Low Power High-Emissivity IR Spatial Uniformity Calibration Source

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Develop compact radiance IR calibration sources for the cryovacuum test facilities with large diameter aperture sizes and low heat loads for use in cryovacuum environments.

DESCRIPTION: Compact radiance IR calibration sources are needed for cryovacuum test facilities that have aperture sizes greater than 27 cm diameter and low heat loads for the cryovacuum environment. Ground testing is a critical test and evaluation requirement for the calibration and characterization of next generation airborne and space-borne imaging systems for field reliability and cost-effectiveness. This testing requires extremely uniform radiometric sources to provide simulated intensity over the full field of view (FOV) of a sensor under test (SUT). Typically, a flat plate is prepared with a high-emissivity surface and instrumented with heaters and temperature sensors to provide spatially uniform emissivity and temperature. The surface may be specially prepared such that narcissus is reduced and that the output is uniform over a range of viewing angles. Temperatures up to 400 K can be achieved but generates tremendous heat in the chamber causing significant radiometric and cooling issues. A uniform illumination source is desired that has an effective aperture greater than 27 cm, an effective spectral emissivity greater than 0.9995 from 2 to 30 µm in wavelength and provides a temperature sensor-based Planckian radiance with a radiance temperature uncertainty of less than 25 mK over a 200 to 400 K temperature range. The radiance accuracy must be maintained over the entire aperture and within a full solid angle defined by an 8-degree cone angle. The entire device must fit into a cylindrical volume that is less than 30 cm diameter and less than 10.16 cm in height. The target total heat load must be no greater than half the heat load that a 27 cm diameter aperture-cavity type blackbody would radiate out the front for any given temperature. The device must survive in the cryovacuum environment and not produce or be susceptible to cryo-contamination. Extension of these concepts to visible sources would be a stretch goal. Phase I should demonstrate (including a calibrated radiance measurement) a prototype uniform-illumination source that produces Planckian radiation equivalent to blackbody radiation (200 to 400 K) over a surface diameter of 15.24 cm and an angular extent of 4 degrees. The temperature stability should be better than 0.2 K and the effective spectral emissivity greater than 0.995 from 2 to 20 µm. The device should fit within a cylindrical volume that is less than 17.78 cm diameter and 10.16 cm in height. The spatial uniformity must be better than 1 perceny. The target total heat load must be no greater than half the heat load that a 15.24 cm diameter aperture-cavity type blackbody would radiate out the aperture at any given temperature within the stated range. Phase II should develop a prototype illumination source that produces uniform illumination at a Planckian radiation equivalent to a 200-400 K blackbody over a surface diameter of 27 cm and an angular extent of 8 degrees. The effective spectral emissivity should be greater than 0.9995 from 2 µm to 30 µm. The device should fit within a cylindrical volume that is less than 28 cm diameter and 10.16 cm in height. The target total heat load should be less than half the heat load that a 27 cm diameter aperture-cavity type blackbody would radiate out the aperture at any given temperature within the specified range.

PHASE I: Demonstrate a prototype illumination source that produces Planckian radiation equivalent to a 200 to 400 K blackbody over a surface diameter of 15.24 cm, an angular extent of 4 degrees and effective spectral emissivity greater than 0.995 from 2 µm to 20 µm.

PHASE II: Develop and demonstrate a prototype uniform-illumination source that produces Planckian radiation equivalent to blackbody radiation (200 to 400 K) over a surface diameter of 27 cm, an angular extent of 8 degrees and effective spectral emissivity greater than 0.9995 from 2 µm to 30 µm.

PHASE III: Military: Developers of IR sensor and IR test equipment to provide more compact & efficient systems for Air Force, MDA & DoD. Commercial: Developers of IR sensors and IR test equipment to provide more compact & efficient systems for customers such as NASA, NOAA, NIST, Ball, Raytheon, SAIC, & others.

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1. Lowry, H., et.al., Test and Evaluation of Space and Airborne Imaging Sensor Platforms in the AEDC Space Sensor Test Chambers, Submitted to the AIAA Journal of Spacecraft and Rockets, Vol. 48, No. 6, November–December 2011.

2. McKee, G., et.al., “Design and characterization of a large area uniform radiance source for calibration of a remote sensing imaging system,” Optical Engineering Application, Part of the SPIE Optics and Photonics, Remote Sensing Instrumentation, Earth Observing System XII, San Diego, CA August 2007.

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KEYWORDS: cryogenic, optical alignment, radiometric source, low power, visible, infrared, IR, radiometer, space testing, radiometric calibration, space imaging sensor testing

AF151-178 TITLE: Infrared Target Collection System (ITCS)

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Research, develop, and deploy a new system for infrared signature measurement of threat targets, backgrounds, and adversary denial and deception devices and targets.

DESCRIPTION: Infrared signature measurement is a process of collecting calibrated infrared images of a target. Calibration refers to the fact that the image is not simply a greyscale infrared image: each pixel in the infrared image will have a radiance value. The "target" will typically be a threat target, such as a T-72 tank.

The signature measurement process has three key requirements:
1. Target measurements are conducted at a fixed location(s). In rare instances customers require measurements to occur at remote locations.
2. Measurements are taken in sets of images throughout a day. Measurements must occur before and after sunrise and sunset, as well as other times to accurately characterize a target.
3. The images of a target must be collected at multiple specific cardinal points for each set, at a constant range for each point. These cardinal points are defined by specific aspect and depression angles, specified by a customer of the data. A typical set of aspect angles will be 45, 135, 225, and 315 degrees, with each aspect angle being measured at depression angles of 0, 30, and 60 degrees. The range to the target must be sufficient so that the infrared cameras can view the entire target in a single frame, and the range must be constant: it must be the same range for each measurement.

It is also noteworthy that each measurement set is calibrated. Calibration sources constitute a separate target. The cameras are interchangeable within the collection system, and are frequently updated as new sensor technology becomes available. Targets can be widely varied in both size and configuration.

There are two traditional techniques to conduct infrared signature measurement to meet the key requirements above, specifically, the third requirement.

These methods have shortcomings which are noted below:
1. The target is placed on a turntable to change the aspect angle, and the sensors are placed on a lift, to adjust the cameras' depression angle. The turntable method is now an invalid signature measurement technique because the target rotation heats the target evenly, and is not considered operationally realistic.
2. The current state-of-the-art method is a collapsible tower (with multiple cameras mounted to the top of the tower) attached to an instrumentation van. The instrumentation van drives to the desired aspect angle, and the tower is raised to the desired height to achieve the required depression angle. The sensors collect the data, and the raw data is transmitted via multiple GigE streams to computer systems inside the van. This method has multiple shortcomings:
(1) The tower must be stowed before the van can be driven. Raising and lowering the tower in this manner significantly slows data collection.
(2) Available commercial off-the-shelf towers that can be operated safely for the van configuration have a limited height, and this limits the depression angles that can be utilized for target measurement. These shortcomings limit the quality of the signature data.

The requirement for this SBIR is an innovative new system to improve three metrics:
(1) The innovative system must increase the speed at which a single set of data can be collected beyond the current state-of-the-art method.
(2) The innovative system must improve collection versatility by increasing depression angles beyond current state-of-the-art. This will be achieved by increasing the maximum sensor height beyond state-of-the-art.
(3) The innovative system must increase total system reliability beyond state-of-the-art.

PHASE I: The Phase 1 solution effort will include a contractor-proposed baseline design compatible with the signature measurement key requirements defined in the "Description" section. Government requirements are solely based on the need to generate valid signature data, and not to dictate or limit potential contractor solutions.

PHASE II: Phase II will consist of a contractor-led engineering phase where the contractor will manufacture and deploy a prototype system based on the solution proposed in Phase I. The contractor will demonstrate that the system at the end of this phase.

PHASE III: During Phase III, the contractor will adapt the prototype Phase II system to a more robust system that meets the unique requirements of other DoD and commercial customers, including those who execute hemispherical observations in other sections of the EM spectrum.

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KEYWORDS: systems engineering, sensing, detection, Camouflage, Concealment, and Deception, CC&D, Denial and Deception, D&D, Intelligence, Surveillance, and Reconnaissance, ISR, IR sensor surveillance, image processing, sensors, imager, MWIR, LWIR, SWIR, infrared

AF151-179 TITLE: <u>Ground Station Antenna Efficiency Improvements</u>

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop technologies that can improve ground station antenna efficiency, particularly as it relates to antenna size.

DESCRIPTION: Antenna efficiencies are a function of numerous components including resonant elements, reflector coatings, and internal feed electronics. The ability to increase antenna efficiency to a level where a significant impact on antenna size is realized requires advancements in numerous technologies and likely the creation of materials that do not currently exist. By increasing the efficiency of antennas, smaller antennas with wider beamwidths could be used in place of large, narrow beamwidth antennas, thereby reducing the majority of tracking and acquisition concerns. Increases in the efficiency of these antennas will more effectively support the tracking of challenging test articles such as missiles.

PHASE I: Perform an analysis of current telemetry system efficiencies compared to other reflector based antennas. Identify concepts and technology methods/areas that could be developed to improve these efficiencies, particularly as it relates to antenna size.

PHASE II: Refine Phase I concept. Mature identified technology areas. Build prototype components and conduct testing to evaluate performance. Conduct system level testing if possible.

PHASE III: All military and commercial applications that stand to benefit from this effort include radio telescopes, satellite communications, and wireless broadband.

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4. Example Antenna Specification Sheet, provided by TPOC and uploaded in SITIS on 1/14/2015.

KEYWORDS: antennas, telemetry, ground stations

AF151-180 TITLE: Recovery Method for Unmanned Hypersonic Test Vehicles

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Research and develop techniques to recover unmanned hypersonic vehicle to maximize data recovery and assess post-flight vehicle integrity.

DESCRIPTION: Research and develop techniques to recover unmanned hypersonic vehicle to maximize data recovery and assess post-flight vehicle integrity. The purpose of this topic is to identify and develop technology to facilitate the recoverability of future hypersonic test vehicles and the data stored on them which would otherwise be non-recoverable. To increase practicality, the new technology must minimize (weight, size, power, vehicle asymmetry) vehicle integration efforts. If successful, the developed capability would improve effectiveness of hypersonic vehicle programs (improve survivability and safety), enhance vehicle concepts and/or provide a foundation for evaluating unmanned hypersonic reusable concepts. As a minimum a successful accomplishment of this topic would facilitate the collection of recorded data (hardware, non-telemetered) at reduce cost for post T&E (test and evaluation) analysis when compared with current over-water TM (telemetry) recovery solutions.

Legacy and current unmanned hypersonic vehicle testing is based on a one vehicle, one flight, non-recoverable/non-reusable constraint. Typically the objective of each flight is to push the boundary in hypersonic technology to enhance the vehicle design, thermal protection system, scramjet demonstration, or guidance navigation and control. Legacy unmanned hypersonic vehicles include X-43, X-51, HTV-2 and HIFiRE which test at most one time per year and cost tens of millions of dollars per test. Unfortunately, the only recoverable element from each test has been the data that is telemetered from the vehicle during each flight.

Recoverable hypersonic technology could significantly improve testing effectiveness by providing programs and testers invaluable insight of new thermal protection systems performance, ablative properties, material effects, scramjet engine operation, and hypersonic instrumentation requirements/optimal locations. A new method could provide a more comprehensive analysis approach that will reduce risk, improve execution efficiency, and enhance vehicle design evolution.

Directly supports Hypersonic Technology Demonstration, T&E of weapon systems, and space vehicles.

Recover methods could improve validation and verification of the system under test.

PHASE I: Research in this phase should focus on the development or provide a methodology to facilitate the recoverability of future hypersonic vehicle systems and data stored on them, by providing an analysis of alternatives, a concept of operation, as well as demonstrate readiness for Phase II. Specific definition of the applicable hypersonic regime should be addressed as applied to the proposed solution.

PHASE II: Research in Phase II should incorporate the best of the current technological knowledge and Phase I success(es) to develop a robust solution. Detailed demonstration of the strategy and testing should be included in the proposal. Detailed documentation should be developed continuously, as well as lessons learned, technology supporting materials, developed hardware and software and should all be delivered at the conclusion of Phase II.

PHASE III: Military Application: This technology could provide improved capabilities leading to more efficient T&E of hypersonic vehicles.
Commercial Application: This technology could provide recovery of scientific experiments or landing space exploration vehicles sent to other space bodies.

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KEYWORDS: hypersonic, flight test, vehicle recovery method, unmanned, technology demonstration, low power, low weight, small size, test effectiveness

AF151-181 TITLE: High Accuracy Moving Platform Surveying/Metrology

TECHNOLOGY AREAS: Weapons

OBJECTIVE: Develop and demonstrate a non-RF-based reference system suitable for accurately determining the time-tagged position of a moving land test vehicle.

DESCRIPTION: Next-generation navigation systems provide very high accuracy measurements in both clear-air and GPS-denied environments. GPS jamming degrades the accuracy of GPS-based reference systems. Other RF-based reference systems suffer similar error sources (multipath, atmospheric, etc) as GPS. An absolute, non-RF-based reference is required to provide a truth reference that is statistically much better than the systems under test.

Current state-of-the-art is a system of ground-based emitters coupled with a rover receiver that operate similar to GPS but in the S-band. This is an RF-based system with similar and possibly correlated error sources as GPS.

The reference system shall operate with a test bed velocity in the range from 0 to 125 km/h. The reference system shall operate on multiple roads located on the White Sands Missile Range (WSMR), N.M., using variable routes.

The time-tagged position data shall be accurate to +/-5 cm/axis rms (thr), +/-1 cm/axis rms (obj) in a GPS denied environment. The data shall be available at >=1 Hz rate.

PHASE I: Research technologies and new applications of them to produce 3-dimensional time-position truth. Assemble an analysis of alternatives to rank possible solutions with respect to technical, cost and schedule risk. Develop a conceptual design of at least one solution worthy of phase II prototype demonstration.

PHASE II: Design, build and demonstrate a reference system operating on one of the 746 Test Squadron land test vehicles on WSMR that experiences measurable elevation, latitude and longitude translation.

PHASE III: Improve the phase II demonstrator and field the reference system on three or more 746 Test Squadron land test vehicles on about 100 to 200 miles of WSMR roads.

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1. http://www.globalsecurity.org/military/systems/ship/cv-design.htm.

2. http://en.wikipedia.org/wiki/Electromagnetic_Aircraft_Launch_SystemTop Fuel.

3. www.wikipedia.org/wiki/Top_Fuel.

4. http://en.wikipedia.org/wiki/Electric_drag_racing.

KEYWORDS: velocity reference, optical benchmark, vision-aided navigation, precise navigation, precision reference

AF151-182 TITLE: <u>Computer Assisted Tomography for Three-Dimensional Flow Visualization in Transonic Wind Tunnels</u>

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a methodology that provides a three-dimensional visualization of compressible flow features such as shock waves and variable density wakes around test articles in large transonic wind tunnels.

DESCRIPTION: Flow visualization techniques are needed that can show the three-dimensional structure of shock waves and compressible flow wakes around the test article in wind tunnels. Transonic wind tunnel testing involves air speeds at which compressibility effects, such as variations in air density occur around the test article undergoing testing. Flow visualization techniques such as Schlieren imaging, shadowgraph, or Background Oriented Schlieren provide images of compressible flow features, such as shock waves and wakes, around the test article. However, these imaging techniques generally provide only one view of the flow around the test article, and are “line-of-sight” techniques that provide little or no information about feature location along the camera’s viewing direction. Images from multiple directions are needed to construct three dimensional images. This can be achieved by using several cameras, or probably less favorably, using one camera and changing the orientation of the test article in the tunnel. Methods for rapidly generating near-real time three-dimensional images from two-dimensional camera images are needed for near-real time testing decisions during wind tunnel testing. Innovative solutions may use, but are not limited to, techniques used in computer-assisted tomography, where images from multiple directions are transformed into three-dimensional information using Fourier transforms, or by some kind of stereophotogrammetry technique.

PHASE I: Demonstrate the viability of the technique using multiple camera images to construct a three-dimensional rendering of an object in the laboratory.

PHASE II: Develop and demonstrate a prototype system for data collection and near-real time three-dimensional structure of shock waves or variable density wakes around test articles in a government-furnished wind tunnel environment or suitable operational environment.

PHASE III: Military Applications: Wind tunnel testing at other facilities that develop and ground test DoD weapons systems. Commercial Applications: NASA wind tunnel testing of commercial aerospace systems.

REFERENCES:
1. Goldhahn, E., and Seume, J. 2007. The background oriented schlieren technique: sensitivity, accuracy, resolution and application to a three-dimensional density field. Experiments in Fluids, Vol. 43. pp. 241-249.

2. Settles, G. S. 2001. Schlieren and Shadowgraph Techniques: Visualizing Phenomena in Transparent Media. Springer-Verlag: Berlin.

3. Goldhahn, E., Alhaj, O, Florian, H., and Seume, J. 2009. Quantitative measurements of three-dimensional density fields using the background oriented schlieren technique. Notes on Numerical Fluid Mechanics and Multidisciplinary Design. Vol. 106, pp. 135-144.

KEYWORDS: schlieren imaging, tomography, Background Oriented Schlieren

AF151-187 TITLE: <u>Physics-Based Damage Modeling of Composites for High-Speed Structures</u>

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop a methodology and tool for damage modeling of a carbon-based or noncarbon-based composite material to examine its behavior as a structural system under thermal, mechanical, and thermomechanical loading.

DESCRIPTION: High-speed flight of future vehicles is a challenging environment for existing material systems and structures to withstand in acreage applications. These conditions are often complex, with interacting thermal, mechanical, acoustic, and vibratory loads that stress structures in ways that are complicated to capture in analytical tools. Detailed understanding of structural behavior in extreme environments, such as that experienced in hypersonic flight, requires a significant improvement in the damage modeling and analysis of high temperature composites (over 1500 degrees F) as they would be used in a structural application. Current modeling is often limited in scope to linear elastic analysis that fails to capture critical stress locations resulting from localized damage in a material modifying the load path. In Phase I, a methodology shall be developed for the damage modeling of a ceramic carbon-based or noncarbon-based composite material to examine its behavior as a structural system under thermal, mechanical, and thermo-mechanical loading. In this context, damage modeling refers to capturing material behavior that is non-linear, in addition to the elastic regime. Preliminary development of an analytical tool should be completed in Phase I, and verified against an existing material property data set, selected by the proposer. The tool should be capable of easy integration into commercial-off-the-shelf (COTS) finite element analysis software such as ABAQUS, and a user's guide for the tool should be provided. While material behavior is important to capture in this effort, focus should be on understanding the resulting impact of material behavior on structural response. The tool should be flexible enough to be implemented in vehicle level analysis without increasing model run-time substantially. The proposer shall also describe techniques for future validation of the tool using physical experimentation, such as static, cyclic, or other standardized testing. The offeror must demonstrate an understanding of the required information necessary to build such a tool, as well as anticipate how a high-speed flight environment will require analysis capable of integrating the multi-axial nature of damage in a structural scale analysis. Phase II efforts should anticipate exercising an appropriate validation and verification process for their tool as described in Phase I, including purchasing of material for testing.

If successful, the methodology and tool will be valuable to the design and analysis of high-speed structures for future systems by capturing stress concentrations in a vehicle early in the development cycle. This reduces the risk of a vehicle design having a critical flaw, which may remain unknown until after the failure of a flight test. The tool could also be applied to other extreme conditions beyond high-speed flight, such as in engine components or aft deck environments. Appropriate coordination with a vendor of finite element analysis software may be beneficial for future commercial application of the tool.

PHASE I: Develop a damage model of a high-temperature composite material to examine its behavior as a structural system under thermal, mechanical, and thermo-mechanical loading. Preliminary development of an analytical tool should be completed and verified against an existing material property data set. The tool should be integrated into off-the-shelf commercial finite element software.

PHASE II: Execute the validation and verification process outlined in Phase I to confirm the ability of the developed tool to capture damage in a material. Purchasing and testing of the material is anticipated. The tool should be further enhanced to understand how it can be incorporated for future analysis of structures from the subcomponent to full vehicle level. Include proposed methods by which this tool could be used to model additional materials beyond what the tool was originally designed.

PHASE III: Work to commercialize the tool and incorporate it into future editions of off-the-shelf finite element analysis programs. The tool should be made more robust to be used with other ceramic-based materials and future testing programs should be utilized to validate the methodology.

REFERENCES:
1. SBIR Topic Number N141-082, "Non-Linear Behavior Models for Design of Carbon-Carbon Composite Components," DoD 2014 SBIR Solicitation.

2. Ray Fertig and Douglas Kenik, "Predicting Fatigue Life Using Constituent-Level Physics," 52nd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 4-7 April 2011. Denver, CO. AIAA 2011-1991.

3. Brian N. Cox, et.al., "Stochastic Virtual Tests for High-Temperature Ceramic Matrix Composites," Annual Review of Materials Research, Vol. 44: 479-529.

4. ABAQUS 6.13 User’s Manual (2012). Dassault Systemes, Pawtucket, RI, USA.

KEYWORDS: damage modeling, ceramic matrix composite, high speed structure, hypersonic, high temperature material

AF151-188 TITLE: Parametric Inlet Bleed

TECHNOLOGY AREAS: Air Platform

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: Develop implementations of porous bleed for SWBLI flow control that enable rapid parametric variation of bleed zones (flow rate/extent), accurate measurement of flow rates, limit variation within and contamination between zones.

DESCRIPTION: Air Force interest in operationally responsive space access and prompt global strike capabilities has driven a need for advanced technologies to provide increased payload, faster response times, and lower operational costs.

Hypersonic air vehicles, using advanced high-speed propulsion systems, represent an approach to meeting these objectives. Bleeding low momentum (boundary layer) flows represents an approach to enhance the performance of a high speed inlet, especially if the inlet is a fixed-geometry design. Such enhancement offers potential vehicle range increases of up to 10 percent (for missiles and aircraft) or increased vehicle payload capacity (for aircraft and launch systems).

High-speed aeropropulsion integration systems are characterized by high Mach number gas flows through a “flowpath” that can include the vehicle forebody and aftbody surfaces (open compression and expansion) as well as the closed duct that connects the air intake and exhaust elements of the propulsion system components. The interaction of the high Mach flows with the aircraft and engine structures generates complex fluid dynamic phenomena that include shock waves, shear layers, vortices, and separated flows, all of which can be further influenced by the thermochemical behavior of the high-temperature air. These fluid phenomena affect high-speed inlet operability and performance, but are not well understood, nor modeled. As such, inlet development often incorporates parametric testing of active and passive flow control approaches, such as bleed. Parametric inlet bleed implemented in the region of shock wave-boundary layer interaction (SWBLI) is particularly challenging due to the dynamic nature of the interaction, which can cause flow recirculation through the bleed holes and attendant loss of their effectiveness. Further, structural limitations can restrict the surface area available for bleed ports and space limitations restrict the volume of the bleed plenum; such restrictions make both the implementation and measurement of bleed flows difficult.

Inlet bleed patterns in high-speed wind tunnel models have historically been implemented by selectively filling or opening holes in plates with large arrays of holes. Dental plaster and high-temperature RTV serve as fill material. Both of these materials require lengthy cure times and are difficult to apply and remove. Second, when tunnel blockage requirements allow, bleed flows are manifolded and measured using a mass flow plug that is located at the end of a long pipe. Often there is not enough tunnel blockage margin to allow use of long bleed pipes and flow plugs. Third, in-stream dividers are sometimes used in the bleed plenum to mitigate flow recirculation in the region of shock wave-boundary layer interactions. These devices are limited by the bleed plate area and plenum volume, and mechanical attachment can be challenging. The state of the art in implementing and parametrically varying bleed flow in the ground testing of high-speed engine inlets severely constrains their development.

PHASE I: Identify parametric inlet bleed approaches designed for M=1.8-3.0, Pstatic ~0.75 atm, Re= 3E6 to 5E6/ft, and Tt~1078 degrees F. Target plenums correspond to Air Force Research Lab SWBLI, which simulates fluid interactions where parametric inlet bleed investigation would be beneficial. Define equipment/processes required including installation/schedule/cost effectiveness & complete bench testing.

PHASE II: Demonstrate and evaluate processes to design, implement, and measure inlet bleed during a parametric experimental test series. Inlet bleed in the region of a single oblique shock wave-boundary layer interaction representative of inlet flow within a mixed compression inlet is the target test case. Although not required, evaluation of the Phase I approach using the SWBLI model in TGF is recommended.

PHASE III: Technologies to increase inlet efficiency can result increased range or payload capacity. Test technologies can be marketed to industry partners that perform high-speed ground testing. Concepts may also be relevant in testing commercial aviation applications.

REFERENCES:

1. Holden, M., "Historical Review of Experimental Studies and Prediction Methods to Describe Laminar and Turbulent Shock Wave / Boundary Layer Interactions in Hypersonic Flows." AIAA-2006-494, January 2006.

2. Tinapple, J., and Surber, L., "Evaluation of Non-Bleed Shock Wave Boundary Layer Interaction Control Using a New Mixed Compression Inlet Simulator Model." AIAA 2012-271, January 2012.

3. Van Wie, D., and Ault, D., "On the Role of Computational Fluid Dynamics in Determining Hypersonic Inlet Performance in Ground Test Facilities." AIAA 1998-2782-353, 1998.

4. Van Wie, D., "Techniques for the Measurement of Scramjet Inlet Performance at Hypersonic Speeds." AIAA 92-5104. December 1992.

KEYWORDS: inlet bleed, high-speed instrumentation, propulsion integration

AF151-189 TITLE: Reduced-Order Fluid-Thermal-Structural Interactions Model for Control System Design and Assessment

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 5.4.c.(8) of the solicitation and within the AF Component-specific instructions. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws. Please direct questions to the AF SBIR/STTR Contracting Officer, Ms. Gail Nyikon, gail.nyikon@us.af.mil.

OBJECTIVE: The intent of this topic is to investigate innovative approaches to creating highly-efficient models of the coupled interaction of thermal response, structural dynamics, and aerodynamics for high-fidelity closed-loop guidance and control simulation.

DESCRIPTION: Flight through the atmosphere at hypersonic speeds can result in the coupled interaction of thermal response, structural deformation, and aerodynamics, known as fluid-thermal-structural interactions (FTSI). Design of an effective control system will require understanding of the system response to associated uncertainties. Uncertainties can come in the form of unpredictable aerodynamic forces and errors in onboard guidance and navigation sensors. Currently, the multi-disciplinary coupling of aerodynamics, thermal dynamics, structural dynamics, and material sciences are not well understood. This is particularly true of their accumulated impacts when traveling through many flight regimes. The impracticality of conducting ground-based experiments that can address characterization of these issues compounds the problem.

While the aeroelastic and control problems in every flight regime are important, most previous research efforts have had limited consideration. For systems operating at very high altitudes there has been considerable work performed, such as for re-entry and information, surveillance, and reconnaissance (ISR) vehicles. However, there are still many knowledge gaps that warrant further study. In particular, many previous efforts have been restricted to limited operating conditions or to simplistic geometries (i.e., airfoils, panels, etc.). There exists no literature documenting the investigation of aeroelastic and control problems on high speed vehicles operating at terminal flight conditions subjected to the extreme structural and thermal loads experienced at high dynamic pressures. This is a niche that has been unique to the weapons community, whose systems are desired to operate in these extreme environments. This topic is motivated by these knowledge gaps and focuses on reduced-order modeling (ROM) of the relevant multi-physics associated with evolving FTSI effects for deforming high speed structures subjected to extreme environmental conditions, such as those encountered during the high speed terminal portion of weapons engagement. An example would be terminal guidance of an air-breathing airframe, beginning with long duration flight above Mach 5 and diving from above 70 kft to the earth's surface.

The state-of-the-art in prediction of these influences includes high-fidelity prediction techniques such as finite element and finite difference models that are computationally demanding. Uncoupled, reduced-order models are also available for structural dynamics that reconstruct the forced airframe response from an orthogonal eigenvector basis directly taken from a finite element analysis of modal response. This modal superposition approach is extremely efficient, allowing real-time simulation of hundreds of modes, but has not been demonstrated coupled to aerodynamic and thermal predictions in a closed-loop weapon simulation environment. Thermal predictions may have the most significant effect on structural deformation and therefore aerodynamics, but an effective approach involving a reduced order orthonormal basis is not apparent. Coupling with the aerodynamics results from the thermal and structural forcing function on the airframe being a direct result of the distributed interaction with the impinging airflow. In return, the pressure and heat transfer distribution is a direct function of the airframe shape, orientation, velocity, altitude, and control surface commands.

The intent of this SBIR topic is to investigate innovative approaches to creating highly-efficient models of evolving FTSI effects for airframes in extreme environments, such as those encountered during high speed flight and the terminal portion of weapons engagement. Ideally the approach would be general and applicable to a wide range of Air Force flight vehicles, although the driving motivation for this topic is hypersonic airframe during long range flight and terminal weapon engagement.

PHASE I: Proof of principal methodology demonstration of coupled aero, thermal, and structural response of an airframe at high Mach number. Tradeoffs between alternate approaches for real-time and non-real time applications are required. During Phase I, simple models would be expected that allow extrapolation to higher levels of fidelity while still characterizing the essential methodologies and process.

PHASE II: A general purpose software/hardware architecture that allows reduced order modeling of coupled flight environment effects in closed-loop integrated guidance, navigation, and control simulations, e.g., real-time hardware-in-the-loop or high-fidelity all digital simulations. The solution approach would be delivered/ transitioned to Air Force Research Lab (source code, documented methodologies/procedures, and characterization of limitations) for integration into in-house simulation architectures.

PHASE III: The objective in Phase III is to establish a standard approach to efficiently modeling coupled airframe environmental influences and to transition that capability to other organizations.This will benefit applications such as long duration flight systems and extended space structures.

REFERENCES:
1. A. Quarteroni, G. Rozza, “Reduced Order Methods for Modeling and Computational Reduction,” MS&A, Vol. 9, Springer Reference, 2014, 334 pgs.

2. N. F. Morris, “The use of modal superposition in nonlinear dynamics,” Computers & Structures 01/1977; DOI:10.1016/0045-7949(77)90061-X.

3. McNamara, J. and Friedmann, P., “Aeroelastic and Aerothermoelastic Analysis in Hypersonic Flow: Past, Present, and Future,” AIAA Journal, 2011, Vol. 49, No. 6, pp. 1089-1122.

4. Culler, A., Crowell, A., and McNamara, J., "Studies on Fluid-Structural Coupling for Aerothermoelasticity in Hypersonic Flow," AIAA-2009-2364, AIAA SDM Conference, Palm Springs, CA, May 2009.

5. Riley, Z.B., McNamara, J.J., and Johnson, H.B., "Hypersonic Boundary Layer Stability in the Presence of Thermo-Mechanical Surface Compliance," AIAA-2012-1549, AIAA SDM, Honolulu, HI, Apr 2012.

KEYWORDS: modeling, simulation, aerodynamics, structural dynamics, thermal response, airframe, coupling, control

AF151-190 TITLE: Environmental Sensors for High Speed Airframes

TECHNOLOGY AREAS: Weapons

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OBJECTIVE: Investigate innovative environmental sensing techniques that meet the needs of safety critical subsystems across the various classes of hypersonic air vehicles being researched.

DESCRIPTION: Safety critical systems rely on environmental sensors to determine if an air vehicle is in a valid flight condition. Current environment sensors used for enabling payloads in conventional air launched vehicles include sensing airspeed (wind driven turbines or pitot tubes), sensing of setback at launch, sensing a programmed flight maneuver, etc. New classes of air launched vehicles are being researched that will maintain a sustained Mach 3 to Mach 6+ as they journey to their destination. Environmental sensors are needed to sense the transition from subsonic captive carry flight to sustained hypersonic flight for the purposes of making a valid flight determination that will be used to enable or activate a payload. In addition to sensing hypersonic unique environments, it is desirable to scavenge power from the environment being sensed such that this environment must be present to provide power to a portion of the safety critical subsystem.

Innovative concepts for sensing valid flight and scavenging power should be able to sense and report the transition from subsonic to hypersonic flight by measuring unique stimuli associated with the different high speed airframes of interest. Concepts should have minimal or no impact on performance of the high speed airframe. The airframes being researched include liquid and solid fuel rocket concepts along with scramjet propulsion. Any concept that needs to access airflow outside of the air vehicle"s skin or thermal protection system must address survivability and correct operation. Sensors mounted inside the airframe must meet the mil temp requirements of -56 degrees C to +75 degrees C. Sensors mounted on or integrated with the propulsion section must survive and operated correctly in their planned environment.

Safety requirements dictate that the environmental sensors and their support circuitry will be dedicated to supporting the safety critical subsystem. The environmental sensor itself and the wiring between the environmental sensor(s) and the safety critical subsystem cannot be shared with any other subsystem on the airframe. To facilitate safety analysis for determining adverse failure modes of the environmental sensors, sensing devices and support circuitry should use discrete components and discreet logic elements.

This topic also needs to address artificial generation of the chosen environment(s) to enable bench top fly out simulations such that environmental sensor performance margins can be tested. If artificial generation of the chosen environment(s) is too complex to achieve under this project during Phase II, then a project plan for developing that environmental simulator needs to be generated as part of this effort.

Understanding the Air Force system safety design philosophy is critical to performing this effort. The references describe the requirements for safety critical sensing and future qualification testing that will be required before the new environmental sensing techniques can be implemented on a tactical airframe.

PHASE I: The contractor will develop the concept(s) through modeling, simulation and analysis. A small-scale demonstration or computer simulation to show proof-of-principle is highly desirable. Merit and feasibility must be clearly demonstrated during this phase.

PHASE II: Develop, demonstrate, and verify the concept technology using high fidelity simulation environment and benchtop stimuli representing notional environment being sensed. Deliverables consist of component demonstration hardware, experimental data, and high fidelity simulations.

PHASE III: Military Application: Apply technology to high speed airframes being used to deliver a payload for tactical military missions. Commercial Application: Apply technology to valid flight sensing on future intercontinental high speed commercial transports, or low earth orbit air vehicles.

REFERENCES:
1. MIL-STD-1316D, Fuze Design, Safety Criteria for.

2. Joint Ordnance Test Procedure (JOTP) -052; Guideline for qualification of fuzes, safe and arm (S&A) devices, and ignition safety devices.

3. Joint Ordnance Test Procedure (JOTP) - 053; Electrical Stress Test.

KEYWORDS: hypersonic airframes, high speed airframes, environmental sensors, fault analysis

AF151-191 TITLE: Hypersonic Materials Selection and Integration Tools

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop tools for industry and government to make informed materials selection and guide the integration of materials for hypersonic vehicles.

DESCRIPTION: High speed weapons and platforms with velocities above Mach 4 will provide game-changing capabilities for the future Air Force. Weapons with velocities from Mach 5 to 12 and platforms with velocities above Mach 4 will place significant demands on materials used for structures, aeroshells, apertures, control surfaces, and for air-breathing systems, propulsion components. The extremely harsh environment of hypersonic flight requires careful selection of materials by linking material and processing (M&P) properties to system requirements. The high speed systems may be expendable or reusable which places different requirements on the M&P selection. Temperatures can range from 1100 degrees F to 3500 degrees F depending on the vehicle and the location on the vehicle. This requires materials like titanium alloys, superalloys, ceramics and ceramic matrix composites (CMC). Making the wrong selection will increase risk, cost and impact system performance. Currently, materials vendors have material property data for the materials of interest at room temperature. However, material property data for typical use temperatures is limited. Example temperatures of interest are 1100-1200 deg F for titanium alloys, 1600-1800 degrees F for superalloys, and 1600-3500 degrees F for oxide, carbon and SiC reinforced CMCs. The availability of high quality, validated data for all system designers is essential for making materials selection decisions.

There is a need to develop methodologies to guide system designers in their material selection process. The methodologies would include components of data compilation with pedigree and validation support, tools and models that utilize M&P data to define the trade space for materials in the extreme environment of high speed flight.

Ultimately, the models need to be implemented into a usable development/design tool and procedures identified for model calibration, verification, and validation. The same tools and models will be used by the government scientists and engineers to create government reference vehicles and support the government evaluation of contractor proposals for future hypersonic system weapon system acquisitions. The materials must be robust, reproducible, and affordable with an adequate design knowledge base to address the M&P challenges included joining, bonding, fastening, sealing, coatings, etc. The application of an integrated computational materials science and engineering (ICMSE) framework with processing data and models linked with property and lifing models is encouraged to enhance the M&P tools.

PHASE I: Identify and determine computational approaches, methodologies, models and design tools to enhance the M&P selection process with a structure to add material properties to guide both government and OEM system designers as the hypersonic systems evolve. Determine approaches to link M&P data to system performance to guide system designers in the materials selection process.

PHASE II: Develop, demonstrate, and validate the tools, models and software needed to provide the capability to conduct M&P trades to support the design of hypersonic vehicles. The products should provide system designers and government scientists and engineers the capability to make M&P decisions or evaluations leading to lower risk and lower cost for future acquisition programs.

PHASE III: Create a marketable package that can be adapted to other materials and systems.

REFERENCES:

1. Integrated Computational Materials Engineering: A Transformational Discipline for Improved Competitiveness and National Security. Washington, D. C.: The National Academies Press, 2008.

2. Integrated computational Materials Engineering for metals using multiscale modeling to invigorate engineering design with science. Horstemeyer Published 2012.

3. Simulation-assisted materials design for the concurrent design of materials and products, DL McDowell - JOM, 2007.

4. ICME at GE: Accelerating the insertion of new materials and processes, DG Backman, DY Wei, DD Whitis, MB Buczek,- JOM, 2006 - Springer.

KEYWORDS: hypersonic materials, high temperature materials, Integrated Computational Materials Engineering, ICME, research and development, integrated structures, hybrid materials

AF151-192 TITLE: Innovative Materials Concepts for Hypersonic Systems

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop new material concepts or systems that will enhance performance, reduce weight, and/or reduce cost for future U.S. Air Force hypersonic systems.

DESCRIPTION: High speed weapons and platforms with velocities above Mach 4 will provide game-changing capabilities for the future Air Force. Weapons with velocities from Mach 5 to 12 and platforms with velocities above Mach 4 will place significant demands on materials used for structures, aeroshells, apertures, control surfaces, and for propulsion components in air-breathing systems. The space shuttle is representative of the state-of-the-art which is a cold structure (aluminum) with a parasitic thermal protection system (TPS) comprised of ceramic tiles and blankets. The X-51A expendable demonstration vehicle used a similar TPS approach. The parasitic TPS adds weight without adding any structural benefit and lacks the durability required for an operational system. New innovative material concepts are required to enhance durability and carry some of the system loads. The goal is to achieve durability without increasing weight and ultimately reducing the structural weight. The extremely harsh environment of flight above Mach 4 generates surface temperatures from 1000 degrees F to 3500 degrees F depending on the vehicle and the location on the vehicle. For Mach 4-5 vehicles, titanium alloys (1100-1200 degrees F) and superalloys (1600-1800 degrees F) can be used for much of the external surface of the vehicle. As velocity increases, CMCs (oxide, carbon and SiC reinforced) will become the material of choice. Innovative material and processing (M&P) solutions will be required to maintain structural integrity and protect the internal systems from the extreme thermal environment. Advanced materials and concepts which are affordable, extremely light weight, structurally efficient, highly durable, maintainable and supportable are sought. The materials development could be directed to possible hypersonic weapon system as soon as 2025 but probably will have more impact on larger platforms in 2030-2035.

Develop and demonstrate new M&P concepts that can be scaled-up and integrated into future hypersonic acquisition systems to reduced cost and risk and enhance performance. Concepts to manage the high thermal stresses in the material at the high temperatures, integrated structures where the structural loads are carried by both the internal structure and the outer skin, and materials concepts for highly efficient sandwich structures are options that could be considered but are not considered the only options. The application of an integrated computational materials engineering (ICME) framework with processing data and models linked with property and lifing models is encouraged to be incorporated from the start to enhance the scale-up and transition to an acquisition program. New material concepts are expected to have the greatest payoff for a reusable platform since cost, weight, and risk will be the dominating factors in the acquisition process. The material concepts may include insulation, seals, bonding, joining, coatings, etc., as well as the integration of dissimilar materials into an efficient structural component.

PHASE I: Identify and define new material, processing and fabrication concepts for the hypersonic application(s). Select the proposed application (vehicle type, anticipated component, predicted environment). Determine the technical feasibility of the proposed materials concept.

PHASE II: Develop, demonstrate, and validate the new material concept and evaluate the performance in the appropriate use environment and the potential for scale-up. Fabricate appropriate sizes and shapes to demonstrate the ability to satisfy the requirements of the selected materials and the fabricated system. Evaluate the fabricated parts to develop the knowledge base to support the ICME tools and models.

PHASE III: Incorporate lessons learned and scale-up material concept.

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KEYWORDS: hypersonic materials, high temperature materials, Integrated Computational Materials Engineering, ICME, research and development, integrated structures, hybrid materials

AF151-193 TITLE: Innovative Synthetic Aperture Radar/Ground Moving Target Indicator (SAR/GMTI) for Hypersonic Air Vehicles

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop innovative synthetic aperture radar/ground moving target indicator (SAR/GMTI) for hypersonic air vehicles. Develop and deliver a simulation tool to estimate the performance SAR/GMTI for various hypersonic air vehicles and trajectories.

DESCRIPTION: In recent years there has been substantial progress in the science and technology of hypersonic air vehicles. Most of the work has been in aerodynamics, propulsion, and materials. However, sensors are critically important for hypersonic missions. Hardly any investigation has been carried out on sensors for hypersonic air vehicles. The domain of hypersonic flight regime is very large, and conditions and parameters can vary by several orders. It is not possible to develop sensor technologies applicable to all regimes. Therefore, we confine our study to flights at Mach 5 to7 at 30 km altitude.

The concept of SAR/GMTI from high speed platforms presents several challenges. Some of them are: (1) High platform velocity leads to broad and extended clutter Doppler spectrum, (2) High grazing angles involved results in large ground clutter, (3) High speed and low altitude flights place limits on field of view of the scene, (4) Slender airframes place limits on the size and shape of antenna aperture, (5) High platform speed place limits on real time SAR/GMTI data processing capability, (6) Radar signal frequency and waveform selection has to meet several different requirements (aperture, atmosphere, range and Doppler resolution), and (7) High airframe temperature results in increased antenna noise and hence reduced signal-to-noise ratio. Besides, there are several conflicting requirements that one has contend in this project: The preferred pulse repetition frequency for SAR and GMTI conflict each other. High range resolution requirement will need wide band waveforms. However, this wide band requirement is not good for antenna beam forming requirement. The proposed approach should address all such factors listed above. This project requires good understanding of the hypersonic airplanes, flight conditions, and aerothermodynamics. It is very important to demonstrate that the proposed SAR/GMTI is applicable to the hypersonic flight regimes that we have described. A simulation tool that will enable one to assess the performance of SAR/GMTI for different hypersonic air vehicles and trajectories must be developed and delivered.

PHASE I: Phase I will focus on the initial design of a SAR/GMTI system suitable for a Mach 5 to 7 aircraft flying at 25 to 30 km altitude. This system should cover a ground swath of 70 km with 1 m resolution. Document technology gaps that prevent development of more effective solutions.

PHASE II: Finalize the design of SAR/GMTI by incorporating the hypersonic flow field in the analysis. Develop a simulation tool to estimate SAR/GMTI performance for various hypersonic vehicles and trajectories. Document, deliver, and demonstrate the simulation tool to Air Force Research Laboratory for further evaluation at the end of Phase II.

PHASE III: Develop commercial SAR/GMTI system for hypersonic vehicles. Government customers may include Air Force, Army, Navy, and NASA. Commercial interests may include sensor developers and system integrators for hypersonic air vehicles.

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KEYWORDS: SAR/GMTI, hypersonics, hot flow environment, high speed air platform

AF151-194 TITLE: Cognitive Computing Application for Defense Contracting

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Create a natural language query system that leverages commercial sector advances in cognitive computing algorithms to provide users insights into Defense contracting statutes, regulations, practices, and policies.

DESCRIPTION: A 2006 GAO report (GAO-06-533SP) commented that "… the challenge of operating in accordance with complex federal acquisition regulations discourages small and innovative businesses from partnering with the government in emerging markets". A significant barrier to partnering with small and innovative companies in emerging areas of research could be removed by providing a clear and intuitive system to understand the requirements of and flexibility within the DoD contracting statutes, regulations, practices, and policies.

Machine learning, natural language processing, computer architectures and enabling technologies are advancing at a rapid pace. Most publicly, IBM Watson competed on the popular game show Jeopardy!, and won decisively. Cognitive computing services are becoming available which provide web-accessible platforms for building interfaces to and front-end applications on, and to which application users can directly query. A cognitive computing application could be developed to address the challenge of making Air Force and DoD contracting more accessible to internal and external customers. Developing such an application would be abetted by leveraging recent commercial and academia cognitive computing advances.

Data sources such as the Federal Acquisition Regulations (FAR), Defense Federal Acquisition Regulation Supplement (DFARS), DoD 5000 series, the Joint Capabilities Integration Development System (JCIDS), systems engineering guidance, Defense Acquisition University training material, relevant sections of U.S.C Title 10, and/or other material as appropriate should be considered as a part of an overall system. Other data sources such as prior contracts, solicitations (e.g. FedBizOpps, grants.gov), and requirements specifications could also be considered.

The perceived initial beneficiaries of this cognitive computing application are likely to be the program managers and contracting personnel of new entrants to the DoD contracting sector. Nontraditional defense contractors and new small businesses could use such a tool to better understand the federal acquisition regulatory requirements. Program managers could benefit from more informed and automated processes related to important areas such as warfighter requirements, systems engineering and risk management. Contracting officers could quickly find answers to difficult questions so that they can focus on creating agreements and use the flexibility available in the procurement regulations. Experienced DoD contractors could use this application to verify their current DoD contracting procedures. Commercialization of this application could involve selling the final product or other developed systems based on the underlying algorithms.

PHASE I: Develop a design architectural concept for an application that uses cognitive computing to provide users answers to natural language questions about the Defense contracting system. The concept should identify possible data sources such as the Federal Acquisition Regulations (FAR), Defense Federal Acquisition Regulation Supplement (DFARS), etc.

PHASE II: Validate by development and demonstration the Phase I design. Evaluate system performance: meaningful answers to a naïve user's questions, evidence presented to support those answers, the answers clarity, and the response speed. Phase II deliverables: (1) working web-based interface prototype, (2) mobile platform interface design, (3) user testing results, and (4) future design iteration improvements. The prototype's latency, scalability and resource trade space shall be measured.

PHASE III and DUAL USE APPLICATIONS: Develop a ready-for-deployment app. Expand the data sources to increase query range. Expand system support to all defense acquisition process phases and milestones, from user needs to system ops and support. Expand the user base from small businesses to large prime contractors.

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KEYWORDS: cognitive computing, natural language processing, machine learning, defense acquisition, defense contracting